HERE'S HOW YOU

CAN DO IT

IN

PHYSICS

Section 4.

HERES HOW YOU CAN DO IT IN PHYSICS

CONTENTS

POOR PHYSICS IN DETERMINING ACCELERATION DUE TO GRAVITY

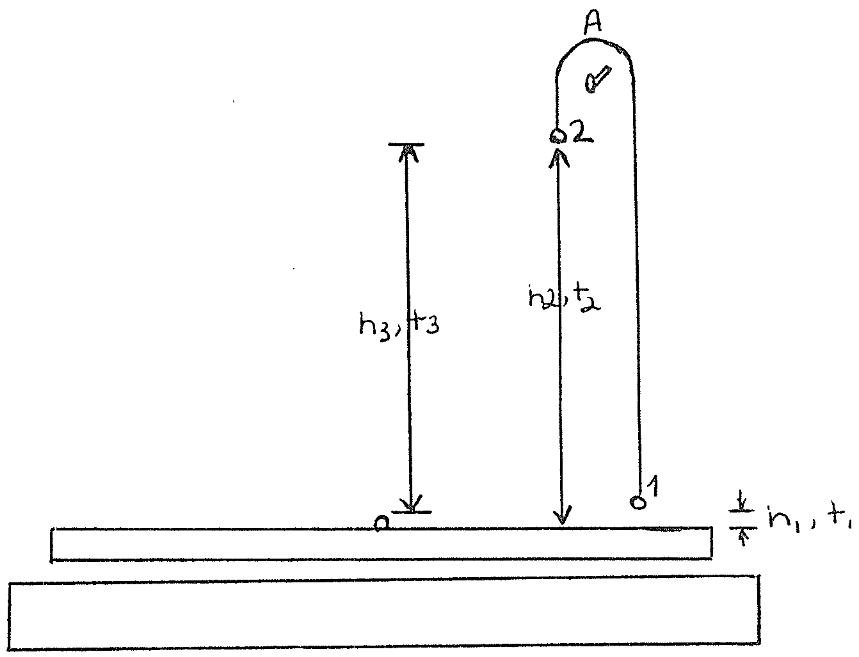
(SEN1979, Vol. 28 No. 4)

Geoff Marsh, Kyogle HS

For some years now, I have found that my students were never able to find a 'good' value for acceleration due to gravity using balls and a turntable. The method is one of several described in Project Physics Unit 1 Experiment 7 which I ask students to choose between to determine g.

I have analysed the results on individual repetitions of the experiment in an attempt to find the major source of error. Unfortunately these analyses have not been very fruitful. Recently I analysed the experimental method in a more general form. The result is that my future students will **not** be using the algebra as suggested in the experimental notes to determine g. Now, why should that be?

Consider the experimental arrangements shown below.



Two balls connected by a string are suspended over a turntable and along a radius of the turntable. On the turntable are a circle of paper and one of carbon paper. As the turntable rotates the string is burnt at A and the balls drop leaving clear marks on the paper. The angle between these marks, and the speed of rotation of the turntable are used to determine the time of fall and hence g.

The purpose of my analysis was to find the expected error in the measured value of g.

Consider the following:
Ball 1 takes a time t_1 to fall h_1 to the turntable
Ball 2 takes a time t_2 to fall h_2 to the turntable
Ball 3 takes a time t_3 to fall h_3 to the initial position of Ball 1

The method which most students use is that the difference in time of arrival of the balls at the turntable ($t_2 - t_1$) is taken to be about the same as the time for ball 2 to fall a distance h_3 (ie. $t_2 - t_1 = t_3$).

Originally I accepted this as a reasonable approximation, but as the following analysis shows, it is far from a reasonable approximation.

Let $\quad h_2 = xh_1$ where $x > 1$.
From $\quad d = \frac{1}{2}at^2$:

$$t_1 = \sqrt{\frac{2h_1}{g}} \; ; \qquad t_2 = \sqrt{\frac{2h_2}{g}} \qquad \text{and } t_3 = \sqrt{\frac{2(h_2 - h_1)}{g}} = \sqrt{\frac{2h_3}{g}}$$

$$\text{Then } t_3 = \sqrt{\frac{2(xh_1 - h_1)}{g}} \; . \qquad \text{and } t_2 - t_1 = \sqrt{\frac{2xh_1}{g}} - \sqrt{\frac{2h_1}{g}}$$

$$\text{That is } t_3 = \sqrt{x - 1}\sqrt{\frac{2h_1}{g}} \quad - (1) \quad \text{and } t_2 - t_1 = (\sqrt{x} - 1)\sqrt{\frac{2h_1}{g}} \quad - (2)$$

Now t_3 is the exact time of fall of ball 2 to the initial position of ball 1 (i.e. through a distance $h_3 = h_2 - h_1$). Also $t_2 - t_1$ is the exact difference in time of arrival of the balls on the turntable.

From equations 1 and 2 above:

$$\frac{t_2 - t_1}{t_3} = \frac{(\sqrt{x} - 1)\sqrt{\frac{2h_1}{g}}}{\sqrt{x - 1}\sqrt{\frac{2h_1}{g}}}$$

OR: $$t_2 - t_1 = \frac{\sqrt{x} - 1}{\sqrt{x - 1}} t_3 \quad — 3$$

Now the value of g calculated by students is :

$$g' = \frac{2h_3}{(t_2-t_1)^2}$$

The relationship between this value and g can be found by substituting from equation — 3

$$g' = \frac{2h_3}{\left(\frac{\sqrt{x} - 1}{\sqrt{x - 1}}\right)^2 t_3^2}$$

ie. $$g' = \frac{x - 1}{(\sqrt{x} - 1)^2} \times \frac{2h_3}{t_3^2}$$

In fact $g = \frac{2h_3}{t_3^2}$ and so the value g' is larger than g by the factor

$$\frac{x - 1}{(\sqrt{x} - 1)^2}$$

In actual experiments, values of x could range from about 8 to 100 depending on the delicacy of the turntable. That is, it is reasonable to expect that;
h_1 = 2cm, h_2 = 16cm at one extreme,
to h_1 = 0.5cm, h_2 = 50cm at the other extreme.

Then the values for g which we would expect the students to calculate are tabulated below:

Table 1

x	$\frac{x-1}{(\sqrt{x}-1)^2}$	Expected Calculated Value of g $g' = \frac{x-1}{(\sqrt{x}-1)^2} \cdot g$ (ms^{-2})	Expected % Error
8	2.09	20.5	109
10	1.92	18.8	92
20	1.57	15.4	57
30	1.455	14.2	45
40	1.37	13.5	38
50	1.33	13.0	33
60	1.30	12.7	30
70	1.27	12.5	28
80	1.25	12.3	26
90	1.24	12.1	23
100	1.22	12.0	22

Even for the extreme of dropping one ball 50cm, the other 0.5cm, students should then calculate a value for g which is 22% higher than the accepted value. If h_1 = 0.5cm, h_2 = 100cm, (your turntable, not mine!) then students should be expected to calculate g as 11.3ms^{-2} - a 15% error.

What if we try to counter these effects, by taking $t_2 = t_2 - t_1$ because t_1 is small? That is, assume that the time measured by the turntable is equal to the time of fall of ball 2.

By arguments similar to those above, the value of g to be expected is:

$$g = \frac{x}{(\sqrt{x}-1)^2} \quad \frac{2\,h_3}{t_2^2}$$

and the values of g calculated by this method are tabulated in Table 2.

Table 2

x	$\frac{x}{(\sqrt{x}-1)^2}$	Expected Calculated Value of g $g' = \frac{x}{(\sqrt{x}-1)^2} \cdot g$ (ms^{-2})	Expected % Error
8	2.39	23.5	139
10	2.14	21.0	114
20	1.66	16.3	66
30	1.50	14.7	50
40	1.41	13.8	41
50	1.36	13.3	36
60	1.32	12.9	32
70	1.29	12.6	29
80	1.27	12.4	27
90	1.25	12.2	25
100	1.23	12.1	23

Clearly this alternative is less acceptable than the method students are asked to use.

Many approximations we make are reasonable and lead to acceptable experimental results. But when a method results in an expected error of 20% (or worse) then the method must be unacceptable. Consequently, I would recommend that this method should not be used.

There is light at the end of the tunnel! A suggestion made to me by Mr. I. Cooper of Sydney Teachers College is well worth using.
It is simply that:

Since $t_1 = \sqrt{\frac{2h_1}{g}}$ and $t_2 = \sqrt{\frac{2h_2}{g}}$

then $t_2 - t_1 = \sqrt{\frac{2}{g}} \left(\sqrt{h_2} - \sqrt{h_1}\right)$

This last expression is quite simply rearranged to give an exact value of g:

$$g = \frac{2\left(\sqrt{h_2} - \sqrt{h_1}\right)^2}{(t_2 - t_1)^2}$$

I don't believe that this expression is too daunting for Year 11 students and all quantities on the right hand side are measurable. It is a simple matter to make sure that the calculations students perform for this experiment are those needed to solve this last equation and I strongly recommend that the necessary changes be made.

SUNSET COLOURS AND BLUE SKIES (SEN 1980, Vol. 29 No. 2)
Margaret O'Donnell, Dip. Ed. student, Sydney Teacher's College

Concepts and Uses

Explanation of blue skies and red sunsets
Scattering of light by particles
White light is a mixture of colours
Colloidal particles
Tyndall effect

Equipment

Aquarium (no smaller than 30x15x15cm)
Slide projector
Aluminium foil or cardboard slide (see below)
Soap solution (1 litre; see below)
Sheet of white cardboard (50x20cm)
Measuring cylinder

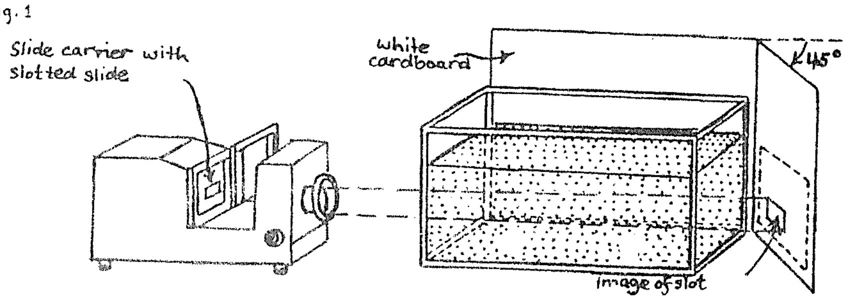
Preparation

1. Soap solution. Dissolve a level teaspoon of Lux soapflakes in a little hot water; dilute to 1 litre.
2. Slide. Cut a horizontal slot (2x1cm) in a piece of cardboard or aluminium foil and fit it into the carrier of the projector.

Procedure

1. Fill the aquarium with clear water to about 2/3 of its capacity.
2. Darken the room and direct the projector beam through the water and focus it, so that it forms a sharp image of the slot on the white cardboard. (See Figure 1.)
3. Add soap solution 50mL at a time to the water in the aquarium and stir to ensure mixing. Before and after each addition invite students to record colours observed in the water and on the screen.

Fig. 1



Explanation

The colloidal particles in the soap solution can scatter light and thus show a strong Tyndall effect. These particles scatter light at the blue end of the spectrum more efficiently than light at the red end. As light encounters an increasing number of particles, more and more colours are scattered out of it, so that the emerging light changes from yellow to orange and finally to red. Colloidal particles (dust, smoke) in the air close to the horizon scatter and hence block, blue light, whilst permitting red light (longer wavelengths) to pass through. Hence, as the sun approaches the horizon, more and more of the blue light is scattered and the sun and the sky appear redder.

BALLOON IN A BOTTLE (SEN 1980, Vol. 29 No. 2)
The two litre 'fizzy' drink bottle has potential for a variety of uses in the classroom. The following activity demonstrates some principles of air pressure.

Hang a long balloon inside the bottle. Stretch the open end of the balloon over the rim of the bottle opening and secure it by screwing on the bottle cap. Punch a hole in the cap with a nail. Punch or drill a hole in the bottom of the bottle.

Inflate the balloon inside the bottle by blowing into the hole in the cap or by sucking air out of the hole in the bottom. Note what happens when you try to inflate the balloon while holding one finger over the other hole. What happens if you cover either hole after the balloon is inflated? What are the effects of changing the size of either or both of the holes?

Since the plastic bottle can be squeezed and popped back to its original shape, it also can be used for an inhalation/exhalation demonstration.

RECYCLE BROKEN THERMOMETERS (SEN 1980, Vol. 29 No. 2)

Broken thermometers usually have mercury left in the bore hole. Because this mercury does not move with temperature change, the 'reading' on the scale remains constant. Broken thermometers are therefore ideal for practising or testing skills in thermometer readings. The answers remain the same and can be self corrected by the student or checked remotely by the teacher.

Several broken thermometers, with sharp edges taped for safety, can be permanently mounted on a portable board to be used as a practice or testing station. Other broken graduated lab apparatus can also be adapted to provide examples of number lines.

Note: If mercury should spill out of a thermometer, all mercury should be picked up at once. Any traces in cracks in the floor should be covered with a chemical ('HgX' powder is available from Government Stores) that will coat the mercury and reduce the vapour pressure.

USING THE DIGITAL COUNTER/TIMER (SEN 1980, Vol. 29 No. 2)

Ray Ceccato, Wade HS

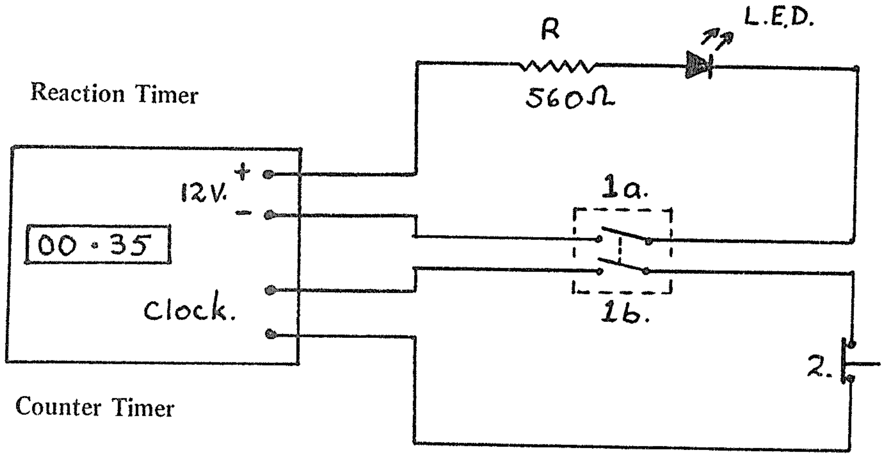
If your school has a digital counter/timer you have probably used it for measuring acceleration due to gravity, or as a reaction timer. Usually this means setting up a temporary circuit each time. This problem can be overcome if permanent modules are constructed.

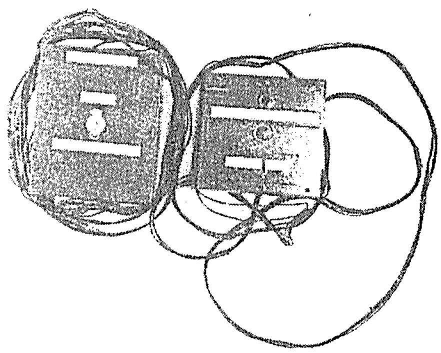
Reaction Timer

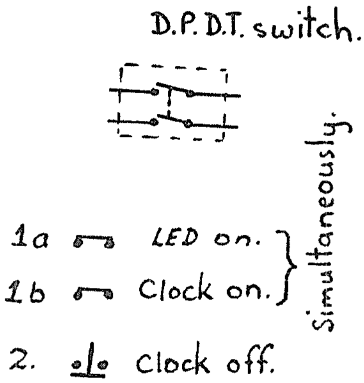
Materials Needed

1. Double pole double throw switch
2. LED and current limiting resistor
3. Bell wire
4. Push button switch
5. Two boxes to house the apparatus

Circuit Diagram







Procedure for Operating

1. Push button switch must be closed to complete clock circuit
2. DPDT switch is rigged so that the clock and LED are switched on simultaneously
3. The person being tested presses the push button to stop the clock when the LED lights
4. After reading the reaction time, the push button switch, the DPDT switch and the digital counter/timer are reset

Applications

1. Biology - finite time taken for nervous transmission
2. Physics - importance of reaction time in driving
3. Just for fun

Measuring the Acceleration Due to Gravity

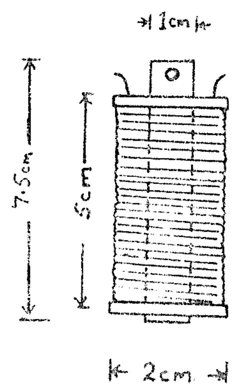
Materials Needed

1. Double pole double throw switch
2. Bell wire
3. Magnet and keeper or other device which will open when hit by a steel ball
4. Electromagnet
5. Optional, steel stand to support apparatus
6. Boxes to house equipment

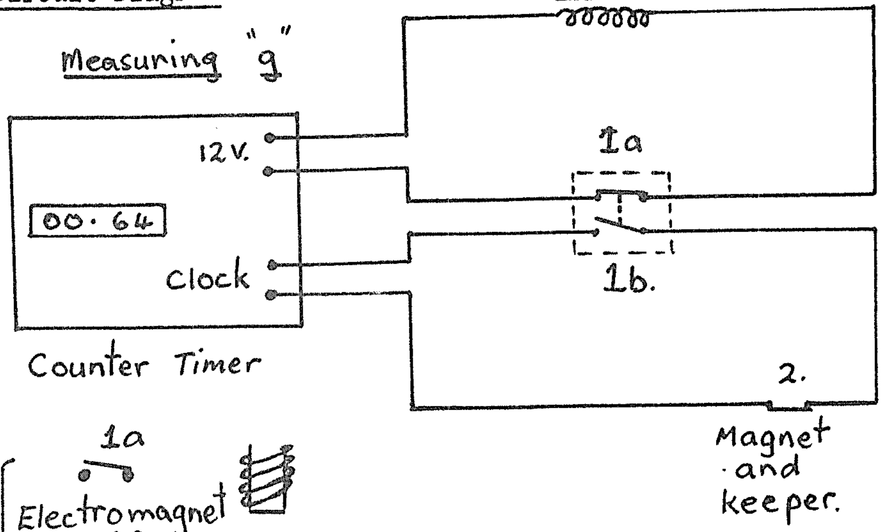
Construction of Electromagnet

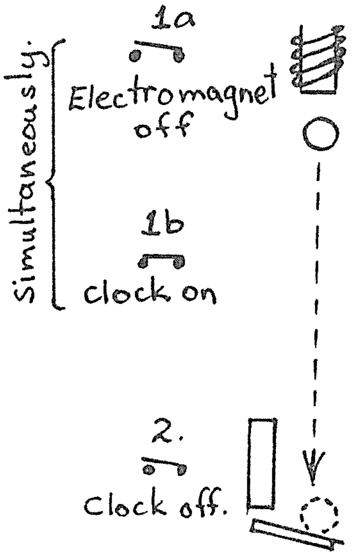
A school type electromagnet will not work from the 12V, 0.25 output of the counter/timer, so a special electromagnet must be constructed. This consists of about 450 turns of 24 SWG enamelled copper wire wound on a 1cm diameter iron core. The 22SWG enamelled copper wire supplied to schools should be suitable, even though it may make the electromagnet slightly bulkier.

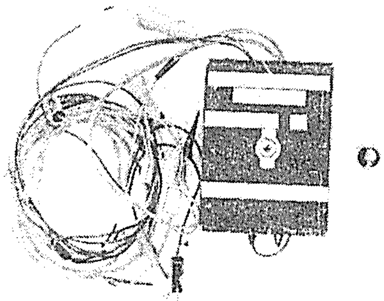
Note: a suitable electromagnet may be available on school requisition, Item No. 992630. Alternatively, a 'school type' magnet can be used, run from a separate 6V DC power supply. - Ed.



Circuit Diagram







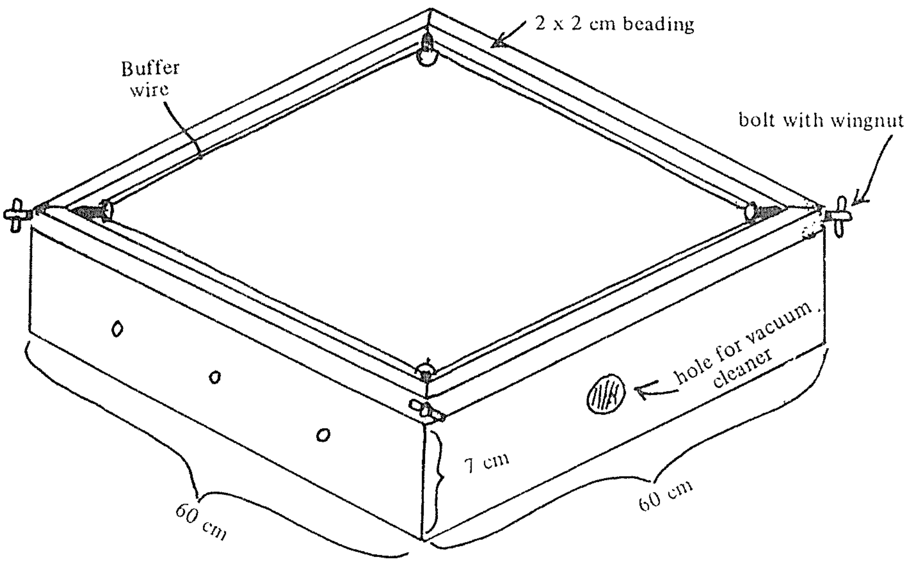
Procedure

1. The DPDT switch is rigged so that the electromagnet is on and the clock is off.
2. Operating the DPDT switch switches off the electromagnet and turns on the clock simultaneously.
3. When the steel ball strikes the keeper, the clock circuit is broken and the clock stops. Acceleration due to gravity may then be computed from $S = 1/2gt^2$ since S and t can both be measured.

Errors can be minimised if the electromagnet is designed to just hold the ball in place, so minimising any time lag between switching off the magnet and the ball falling. Slips of paper between the ball and the magnet can serve this purpose. S should be made as large as possible to reduce timing errors. This arrangement is much easier to use than the Venner clock, in which the current to the electromagnet is interrupted each time the clock passes zero. As well, the setting up time is reduced.

MAKING YOUR OWN AIR TABLE (SEN 1980, Vol. 29 No. 3)
C.J. Craven, Canowindra HS

In a number of experiments in senior physics, an air or bead table is a very useful if not essential item. To buy one of these already manufactured can be very expensive. While bead tables are cheaper, they have disadvantages, especially with the beads. I have found that an air table can be manufactured for little expense or expenditure of time.



The full scale dimensions of the table are 60cm x 60cm x 10cm.
The first stage is to make your basic frame of timber, about 7cm x 2cm, which is glued, butted and nailed together. Better joints can be used but they are not necessary. Onto this is glued and nailed a sheet of masonite.

Now comes the exciting part! Using a 2.0mm drill you now drill holes every 1.5 to 2cm apart over the entire surface. (This might be a good job for a misbehaving student.) When this is completed, another sheet of masonite is glued to the base.

The next step is to attach beading around the edge. This is done with wood approximately 2cm x 2cm and is nailed around the top edge of the box. Drill a hole through this beading at each corner approximately 7mm in diameter. Through each of these holes you can then place a 5cm x 6cm cuphead bolt with a wing nut. Behind the cup head on each bolt, drill a hole about 2.0mm so that wire may be threaded through.

Take a piece of monochord wire or unravel a strand or two of picture hanging wire through all four bolts. Pull it fairly tight and join the ends. The wing nuts can then be used to adjust the wire to the correct tension. You now have a buffer which the puck can bounce off.

The last step is to cut a hole in the side of the table big enough to put a vacuum cleaner hose in. You may find, when you start it up, that the masonite will bow out due to the air pressure. I have found that you can drill a number of 10mm holes around the sides until enough air can escape to allow the masonite to stay flat. I have found that petri dishes with elastic bands around the edges make good pucks and bounce off the wire nicely. Sizes shown here are only used because of the size of the material at hand. I have found it a convenient size, however, for both work and storage.

ACCURATE MEASUREMENT OF LENGTH FOR YEAR 7 (SEN 1980, Vol. 29 No. 4)
Graeme Cox, Karabar HS

Aim
To familiarise students with an accurate method of measurement of length (either in place of using a micrometer or as an introduction to a micrometer).

Method
Students (in groups of 2 or 3) are issued with a 'G' clamp. They then wind the 'G' clamp to the fully open position and measure the distance between the two jaws, to the nearest millimetre. The students then count the number of turns required to close the jaws together.

By dividing the total length by the number of turns, students now have a reasonably accurate method of measuring length. This is obtained by counting the number of turns required and multiplying this by the length of each turn. Students then measure a number of objects, several times.

Questions
1. Does one article always measure the same length?
2. Why do errors occur?
3. How would you improve or modify a 'G' clamp to improve its accuracy for measuring length?
4. Draw a diagram to show how these would be incorporated to make a micrometer. (Then compare students diagrams with an actual micrometer.)

THE MOTOR DRIVEN STROBOSCOPE (SEN 1980, Vol. 29 No. 4)
Harry Slip, North Sydney Technical College

One of the most intractable devices currently used in the physics laboratory is the motor-driven stroboscope. Attempts to select an accurate disc speed using the strobe pattern supplied (Figure 1) are often foiled by changes due to disc orientation, motor heating, etc. This problem can be overcome using paddles.

Initial attempts to control the disc rotational speed involved building a combined precision voltage and current source with a high degree of control resolution (see circuit diagram, Figure 2). It was expected that, since the motor speed (and hence the disc speed) was proportional to the current flowing through the motor windings, the current source would be more effective than a voltage source in controlling the motor's speed. These expectations were confirmed, but although the disc speed could be accurately set with a current source of about 1 milliampere resolution, this speed changed markedly with disc orientation. It was then concluded that the dynamic and frictional characteristics of the motor were dominating the situation. (Note that the precision current/voltage source would be worth building for other experiments in which a constant current or voltage supply is required)

In order to dampen the characteristics of the motor (or to provide a well-behaved load for the power supply/motor system to work against), flat paddles were fitted to the strobe disc as in Figure 3.

Testing the arrangement showed instant success. The speed of the stroboscope was found to be so insensitive to motor current that an ordinary 10ohm laboratory rheostat in series with a standard laboratory power supply gave excellent control and stability. Also the strobe speed was insensitive to disc orientation. The method would probably be just as successful with camera-mounted strobes.

If the paddles are detachable they can be varied in size by cropping them equally with scissors. It would then be possible to have sets of paddles that tuned the stroboscope to operate at the various required strobe rates.

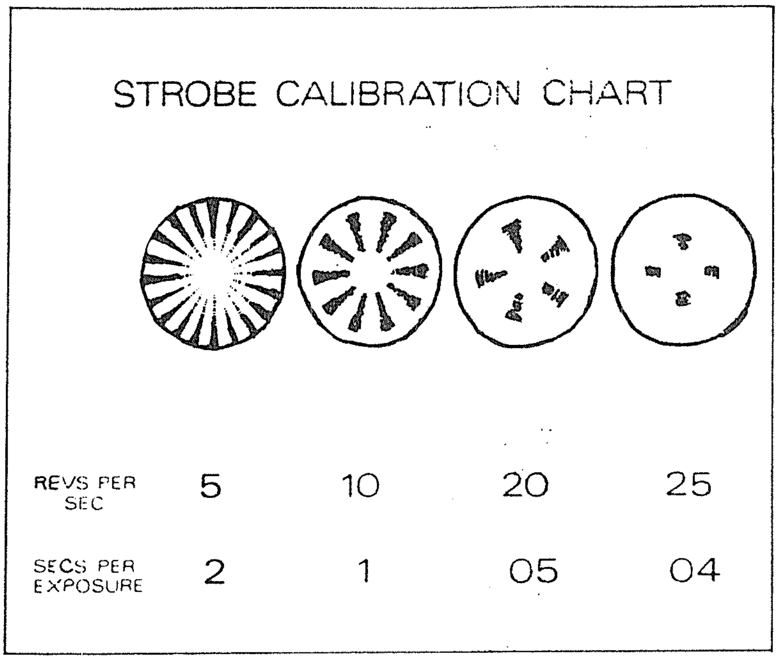


Figure 1

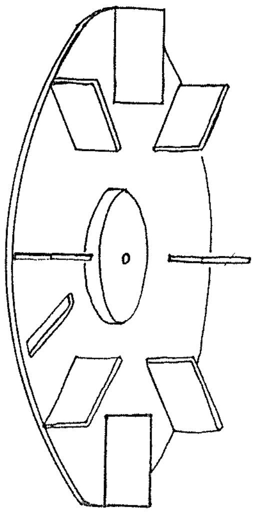


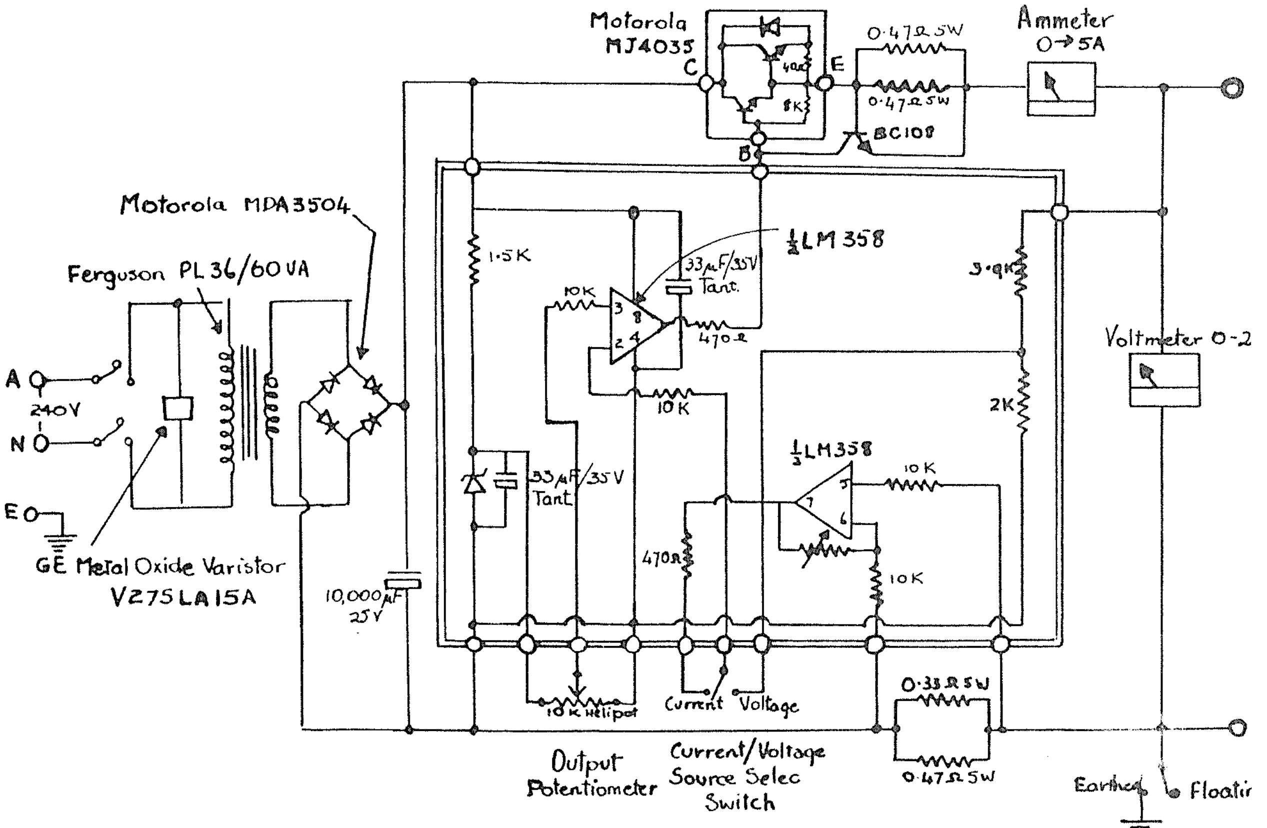
Figure 3

Parts Distributors

All resistors and capacitors—
Sheridan Electronics, Redfern
Dick Smith
George Brown
Radio Despatch

Mains Switch, DP/DT Illuminated—Dick Smith.
Bridge Rectifier MDA 3504—Silicon Valley, St. Leonards.
LM358 Operational Amplifier—Semtech, Lane Cove.
Ammeter, Voltmeter and BC108 or similar—Dick Smith.
Power Darlington MJ4035—Silicon Valley.
Ferguson Transformer PL 36/60 VA—Sideband Electronics, 213 Hawkesbury Road or Box 23, Springwood, 2777.
Phone: (047) 54-1392.

Figure 2



Precision Current/Voltage Source

SHOOT OUT (SEN 1980, Vol. 29 No. 4)
Genella Gerardi, Cheesequake School, New Jersey

Have you ever had students shooting rubber bands in class while they were supposed to be doing something else? This disruptive behaviour can be channelled into a learning activity. Divide the class up into pairs of students and give each pair rubber bands of uniform size, a centimetre ruler and a meter stick. Provide the following instructions:

1. Hold the ruler on the edge of the desk.
2. Hook the rubber band on the end of the ruler and pull back to the 12cm mark.
3. Let the rubber band go.
4. Measure flight distance with the metre stick.
5. Repeat four times and record data.
6. Repeat the above, but pull rubber band back to the 16cm mark and then the 20cm mark, five times each, and record the data.
7. Average the distances for each pull.
8. Record the averages for each student pair and determine the class average for each pull.
9. Make a list of variables affecting differences in flight distance.
10. Graph the stretch of the rubber band and the distances travelled.

Sixth graders have enjoyed this activity immensely. The shoot out can be repeated using rubber bands of different sizes and comparing the results. Also the ruler can be placed at different heights such as on a low table and a high bookcase and measurements taken.

OVERLOAD PROTECTION FOR CURRENT METERS (SEN 1981, Vol. 30 No. 2)

Mike Gunnourie, Sydney Teachers College

It doesn't matter how much you tell them, they still connect ammeters, mill- and microammeters and galvanometers directly across power supplies and burn them out. Some models have built in fuses but most don't. Current meters at Sydney Teachers College have been overload protected simply and cheaply by removing the base plate and replacing one of the leads from the terminals to the meter movement with a piece of fine wire. Proper fuse wire might serve but, having none handy, it was found that a single strand of the wire inside normal plastic covered hookup wire would burn out at currents from about one to five amps, depending on the brand. (Test a piece with the desired length - about five centimetres- using a power supply and ammeter to determine its maximum current rating.) Even microammeters will tolerate an ampere or so for an instant without damage.

The resoldering job is simple enough to be given to some students and perhaps making the person who 'blew' the meter fix it would have some educational merits.

ACCELERATION MADE SIMPLE (SEN 1981, Vol. 30 No. 2)
J.B. Muir

The concept of acceleration is often made more difficult by the complexities of the analysis of ticker tapes. This same analysis tends to obscure the outcome of investigation of accelerations down inclined planes and the relationship between force, mass and acceleration.

Provided that some work has been done to show that the acceleration down an inclined plane, or that produced by a constant unbalanced force, is uniform, we can use the following technique for more routine measurements.

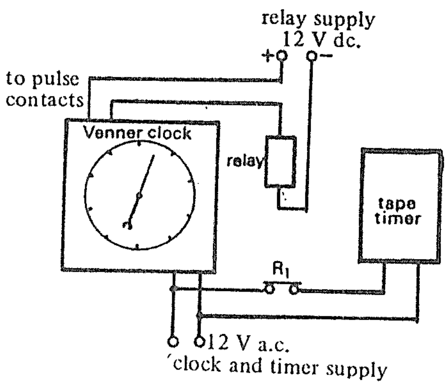


Figure 1. Tape timer control circuit.

Assuming acceleration to be the change in velocity in one second then if we measure two velocities at the beginning and end of a 1s interval:

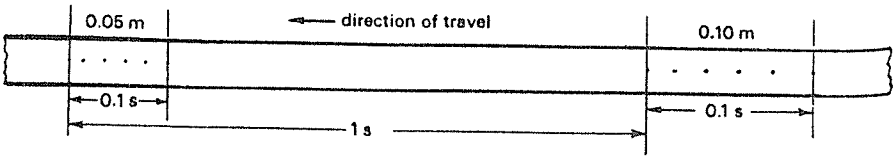
$$\text{acceleration } (ms^{-1}) = \frac{\text{final velocity } (ms^{-1}) - \text{initial velocity } (ms^{-1})}{1s}$$

This can be achieved in practice using the Mk 1 Venner clock to control the low voltage AC supply to a tape timer as shown in Figure 1.

During the 1s sweep of the Venner clock when set to run continuously, the pulse contacts are open between zero and 0.1s and closed between 0.1s and 1s. This mode has to be reversed to operate the tape timers so that dots are produced on the tape for 0.1s at 1s intervals. To do this a 12V relay, fitted with a pair of normally closed contacts, is energised via the pulse contacts. These contacts

(R_1) switch the 12V AC supply to the tape timer, causing it to print six dots at 1s intervals on the tape. If the timer is vibrating at 50 Hz, the five spaces produced represent 0.1s.

This arrangement is most conveniently operated from one power supply giving both the 12V AC and the 12V DC. This is switched on when a run is to be made. A possible analysis of results is shown in Figure 2.



$$\text{initial velocity} = \frac{0.05}{0.1} = 0.5\ \mathrm{ms^{-1}}$$

$$\text{final velocity} = \frac{0.01}{0.1} = 1.0\mathrm{ms^{-1}}$$

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{1\mathrm{s}} = \frac{1.0(\mathrm{ms^{-1}}) - 0.5\ (\mathrm{ms^{-1}})}{1(\mathrm{s})} = 0.5\ \mathrm{ms^{-2}}$$

Figure 2. Typical tape, and analysis of data.

In practice a friction compensated plane has to be chosen which is long enough for the run to take more than 1 second.
(Reprinted from School Science Review 58, 497-498, March 1977.)

THE SALT FOUNTAIN OSCILLATOR (SEN 1981, Vol. 30 No. 4)
Ray Linabury, Canterbury BHS

This is a simple but elegant demonstration which makes use of the density difference between salt and fresh water.

1. Pour cold water into an 800mL beaker until it is about 3/4 full. Obtain;
   a paper cup and place a pin hole in the bottom of it. Prepare a salt solution about equal to half the volume of the cup, using 11/2 to 2 teaspoons of salt. Stir the solution thoroughly so that all the salt dissolves. Add enough dye to colour the salt solution.
2. Lower the cup into a beaker whilst , at the same time, pouring the dyed salty solution into the cup. Adjust the cup so that the water level inside is as close as possible to the water level outside. Fix the clip into position by taping some glass rods to its sides so that it is supported by the edge of the beaker, as shown in Figure 1a.

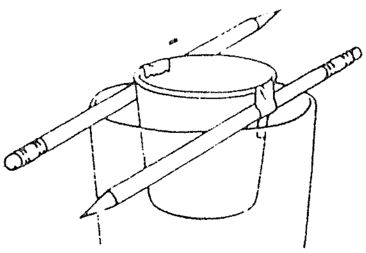


Figure 1a.

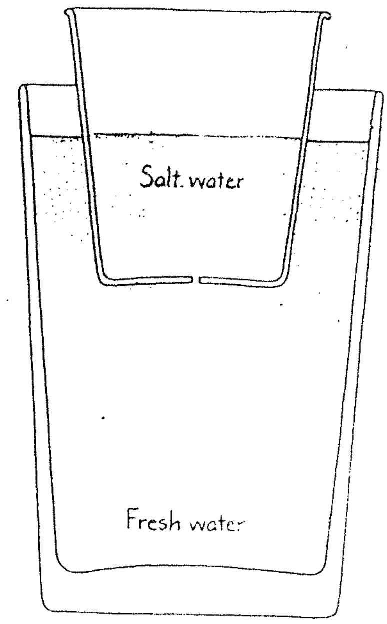


Figure 1b. *The basic salt oscillator*

You may need to place a small weight of some kind on top of the cup to keep it down. When the cup is in position a stream of coloured salty water will begin to flow out of the pinhole. The coloured water will collect on the bottom of the beaker due to its greater density, as shown in Figure 1b. After several minutes the flow will stop for a few seconds and the oscillation will begin. The period of oscillation varies according to the size of the hole in the paper cup. However a pinhole generally gives a flow of about 20 seconds and a period in which nothing appears to be happening of about 30 seconds. Oscillations will continue for up to 12 hours.

A TECHNIQUE FOR PRODUCING SKETCHES AND LINE DIAGRAMS
(SEN 1981, Vol. 30 No. 4)
C.L. Fogliani and I.T. Townsend, Mitchell CAE

A picture is worth a thousand words and students certainly come to understand the gist of an experiment if they can see a realistic picture as well as printed instructions. The trouble is normal photographs suffer from certain inherent disadvantages:

* they are usually continuous tone rather than black and white; this means that they generally need sophisticated equipment and considerable expertise for copying or duplicating
* they often contain too much information; this can be of two types - a distracting background or too much complexity in the subject itself; often this can only be solved after much trial and error with lighting, camera angles, backgrounds, etc.

The technique to be described overcomes some of these problems; the resulting pictures are high contrast, black and white, greatly simplifying reproduction. Only the required amount of detail need be recorded in the final product. This is largely in the hands of the teacher within the limitations of the method.

The first requirement is to produce a photograph of the apparatus or technique of which the sketch or line diagram is desired. One does not need to be a good photographer nor does one need a lot of photographic equipment to do this. We use a SLR fitted with standard lens and electronic flash. A perfectly suitable set up is a polaroid camera loaded with 105 (B&W) film. Colour film is not suitable. The technique or equipment is photographed from a variety of angles. It is desirable to use a brightly lit area or a flash unit so that a small aperture can be used at hand-held speeds (1/30 - 1/60sec). The film is processed in the normal way and prints produced on resin-coated paper of the same size as required for the final diagram. With polaroid prints, care should be taken to ensure that the polaroid print size is suitable for the use intended.

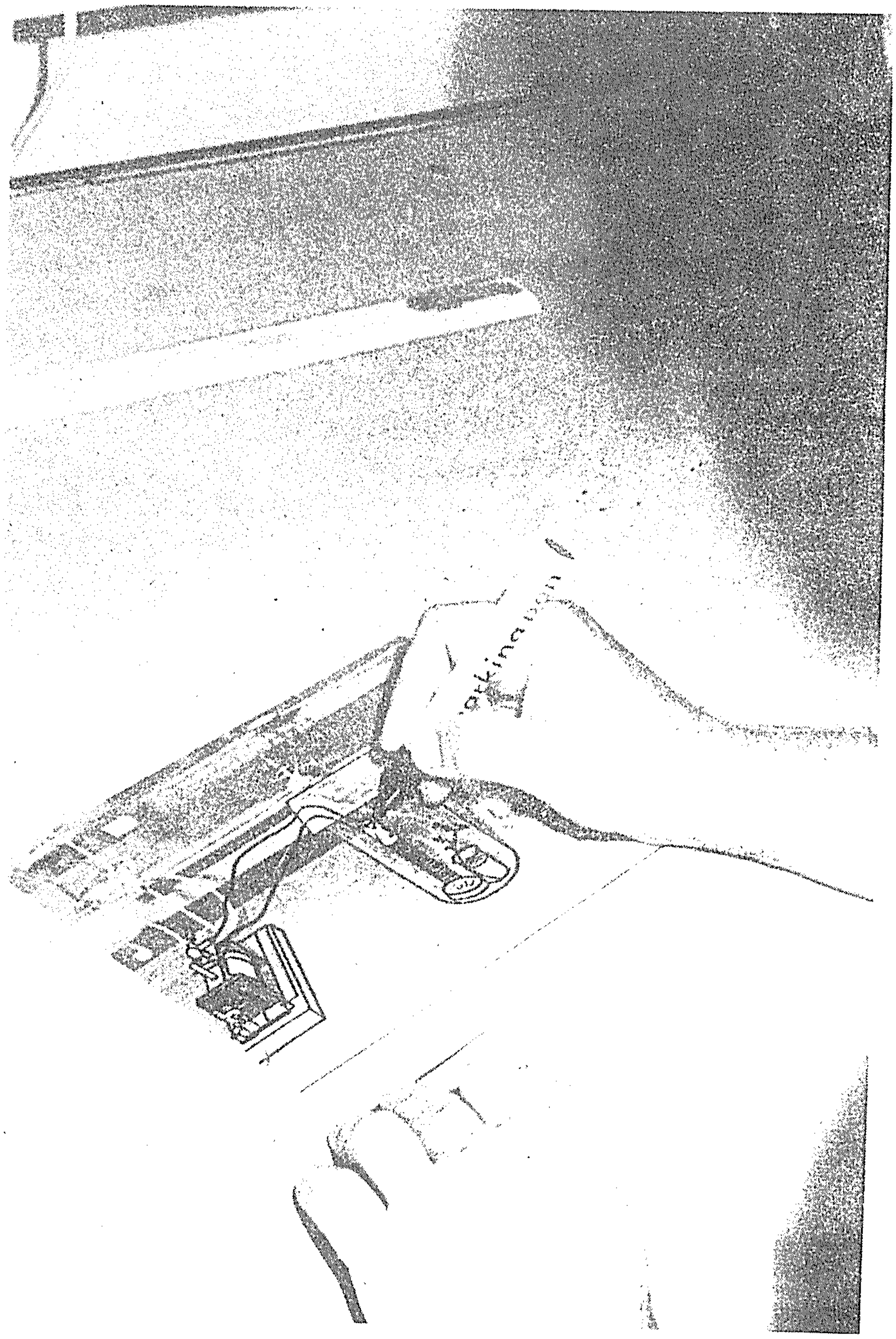
The teacher then traces over the parts of the print desired for the diagram (Photograph 1). The photograph is then bleached (Photograph 2). Several formulations of photographic bleach are possible, but the one we use is:
100g $CuSO_4.5H_2O$ (lab grade), 100g Na Cl, 10mL conc. HCl, then water to 1L.

Dip the prints into the bleach until all the photograph disappears. The ink outline should remain. Several makes of felt-tipped pens produce a good result. Indian ink is not suitable since it tends to flake off.

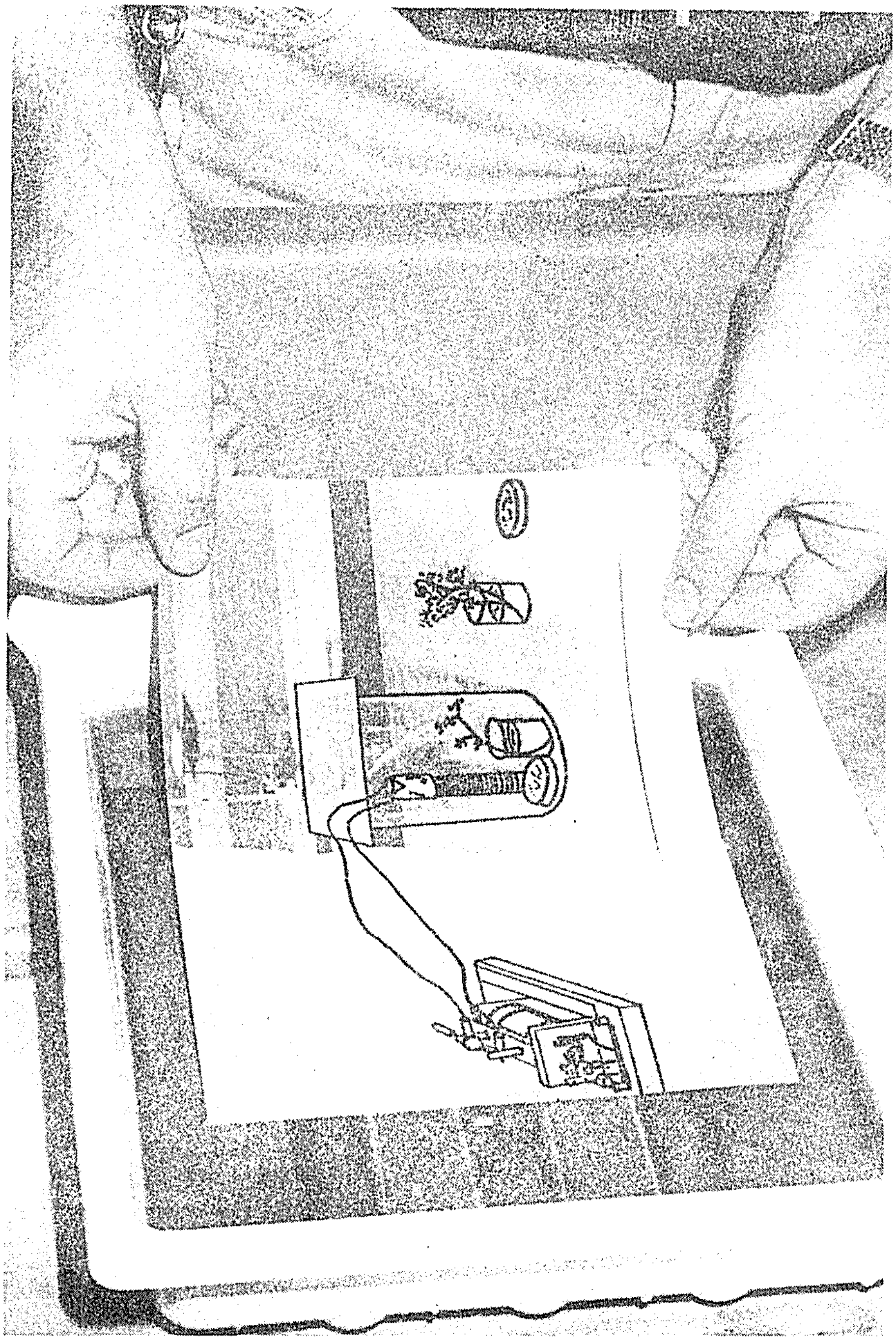
The print is then fixed again and dried. Prints treated in this way will photocopy very well; they can also be used to make thermal stencils and overhead projection transparencies.

The page shown was produced for a laboratory manual in a chemistry course at Mitchell CAE. the authors have also employed the method in producing a first draft of the Environmental Chemistry Module of the Academy of Science's High School Chemistry Project.

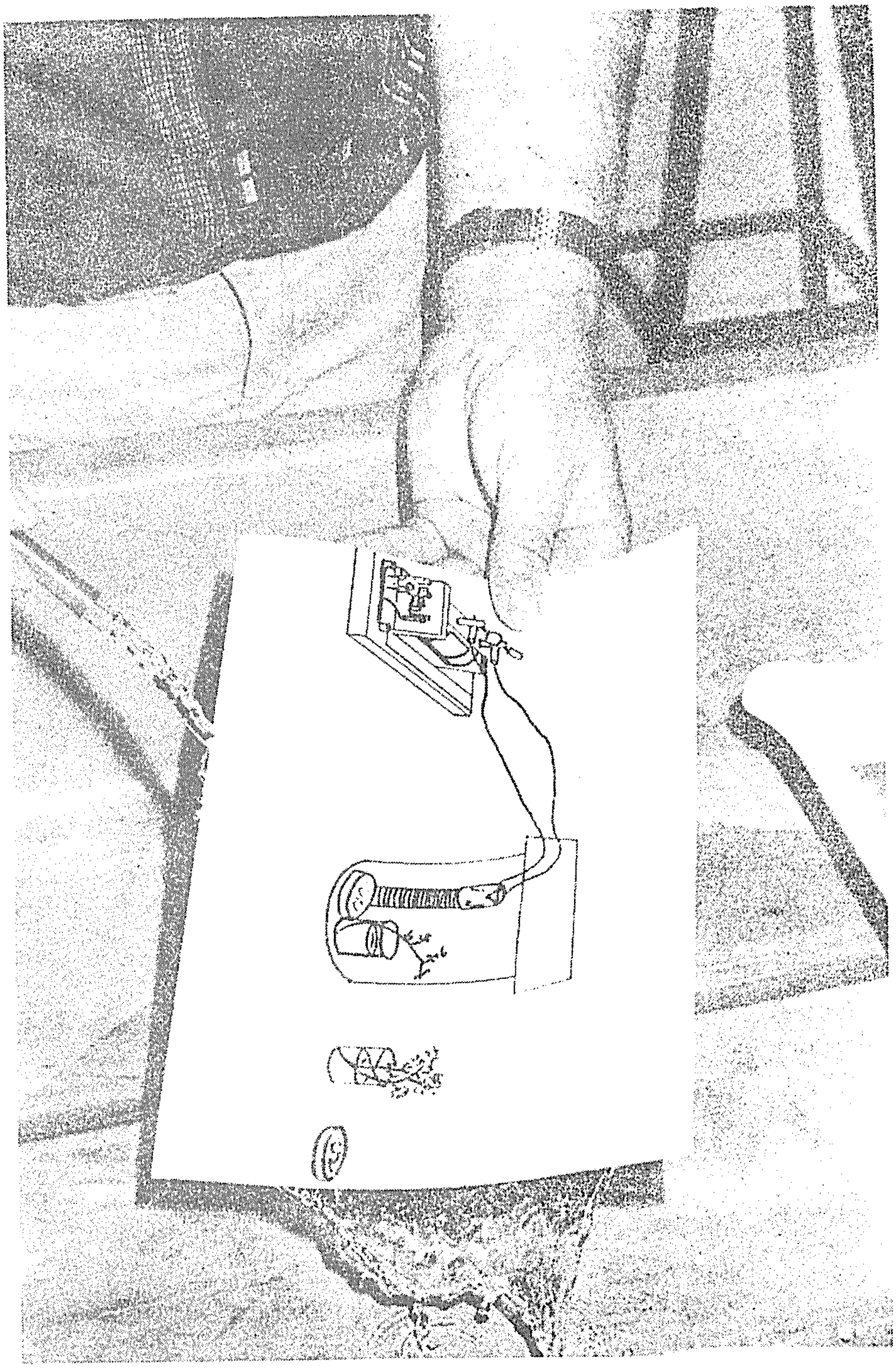
Some stages in the process



1. Going over the objects on the print.

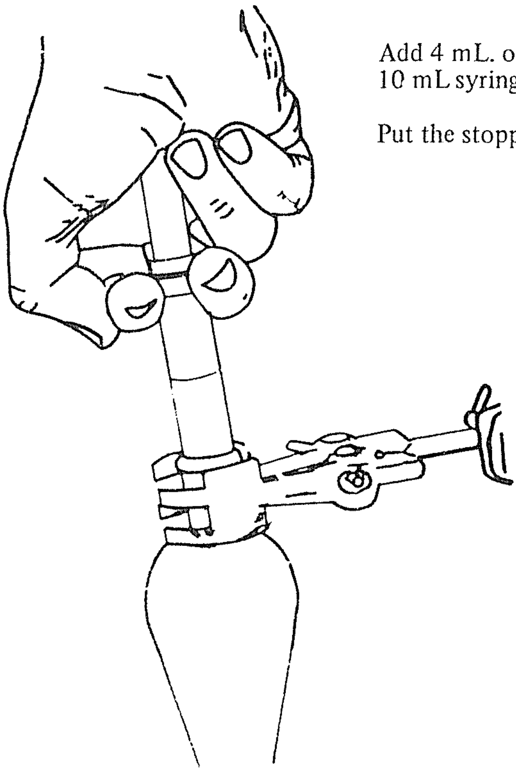


2. Bleaching the image.



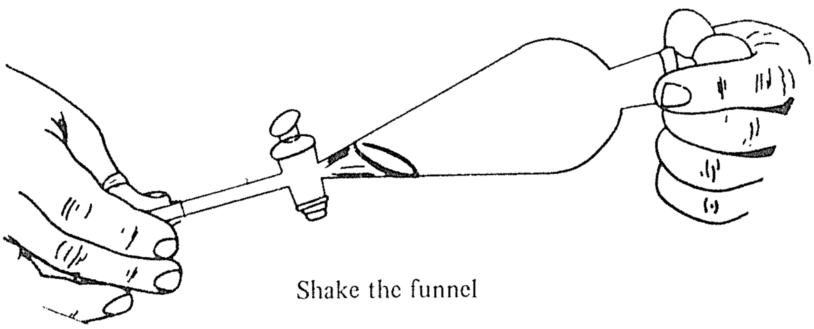
3. Washing

Analysis for Carbon Dioxide



Add 4 mL. of 60% KOH using the 10 mL syringe.

Put the stopper on quickly.



Shake the funnel

LASERS (SEN 1982, Vol. 31 No. 1)

Phil Greaves, Penshurst GHS and Brian Connor, Sydney Technical HS

A.

Introduction

The first laser was built in 1960 by Theodore Maiman, a research scientist working for the Hughes Corporation. His research paved the way for the development of a fantastic array of fascinating devices and very useful tools. Today, lasers are used in surveying, geophysical measurements, medical applications, electronic component manufacture, atomic fusion research, precise distance measurement and a host of other applications.

1. What is a Laser?

A laser is simply a light source, but it has several differences from a normal light source.

a) The light from a laser is pure or monochromatic light, occurring at a specific frequency (or frequencies).

b) The light is coherent, that is, if light is considered as a bundle of waves, the laser light has all the waves in the bundle in phase where the crests of one wave coincide with the crests of every other wave in the bundle. This must follow from the fact that the light is monochromatic as only waves of the same frequency can be in phase all the time.

All waves in phase.

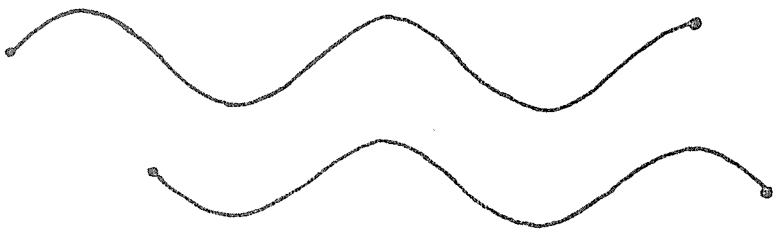


Figure 1.

c) Laser light is highly directional. Only light on the axis between the mirrors of the laser device is allowed to escape. The beam which does emerge is narrow and well collimated. It diverges only a tiny amount rather than spreading as does the beam from a torch or spotlight. At 50 metres from the laser the beam is still less than 1cm in diameter.

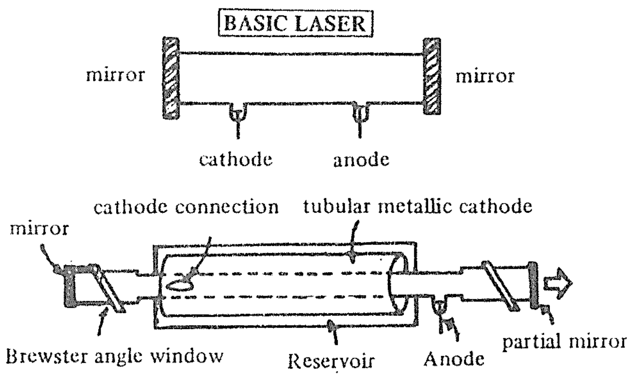
d) Laser light is extremely intense even from a small, low power laser.

A 1.0 milliwatt laser produces a beam with the same intensity as the sun.

2. How is Laser Light Produced?

Though the laser is a fairly recent scientific development the fundamental idea behind its operation has been with us since the early 1900s. The actual process of producing laser light involves theories from quantum theory, atomic physics and energy levels of orbital electrons.

There are many different types of laser devices available, however the helium-neon laser (usually available in schools) only will be discussed. This laser consists of a glass tube containing two metallic electrodes and a gas mixture of about 90% helium and 10% neon. The gases are confined under a pressure of about 1 to 3 kilopascals. The ends of the glass tube are precision machined and mirrored, one mirror being slightly transmissive and the other totally reflective.



A practical Laser.

Diagram 2.

To start laser action within the tube a high voltage, in the order of 8 to 10 thousand volts, is applied to the electrodes. This causes a glow discharge within the gas mixture. At this stage electrons in the atoms of both gases jump from their ground state energy level to a higher energy level. When these electrons return to the ground state they emit light of a particular frequency, depending on the energy released by the electrons. There are two ways an electron can emit this energy;

a) by **spontaneous emission** where the photons of light are emitted in all directions **randomly**.

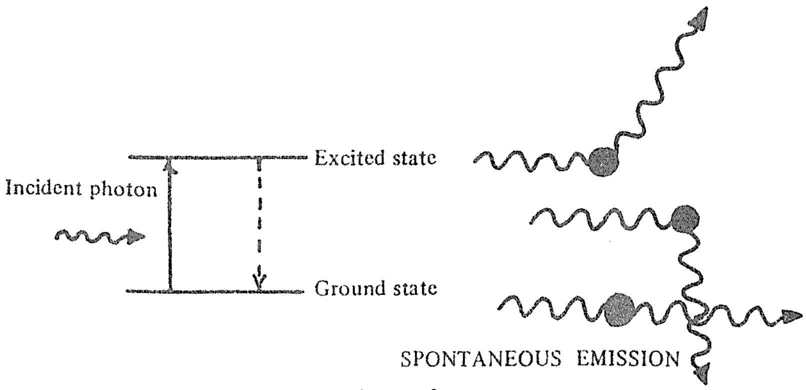


Diagram 3A.

b) by **stimulated emission** where the excited electron is stimulated into releasing its energy by the interaction of a photon of light. In stimulated emission the energy of the incident photon and the energy released by the electron are the same, so two photons of light are produced which are in phase. This is **coherent** radiation.

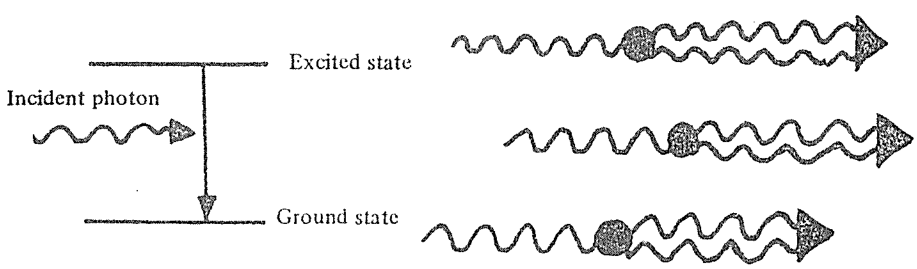


Diagram 3B STIMULATED EMISSION

Normally only about one in 10^5 atoms is in the excited state of 1 000K, so very little coherent radiation is produced. It is essential for laser action to have a condition in which the number of excited atoms exceeds the number of atoms in the ground state. This is known as a population inversion. If this population inversion can be sustained then photon multiplication can occur.

Pumping, the process used to maintain the population inversion, is accomplished by the use of the helium gas. Two energy levels for helium coincide closely with two energy levels in neon. Energy transfer between excited helium atoms and ground state neon leads to large populations of excited neon atoms.

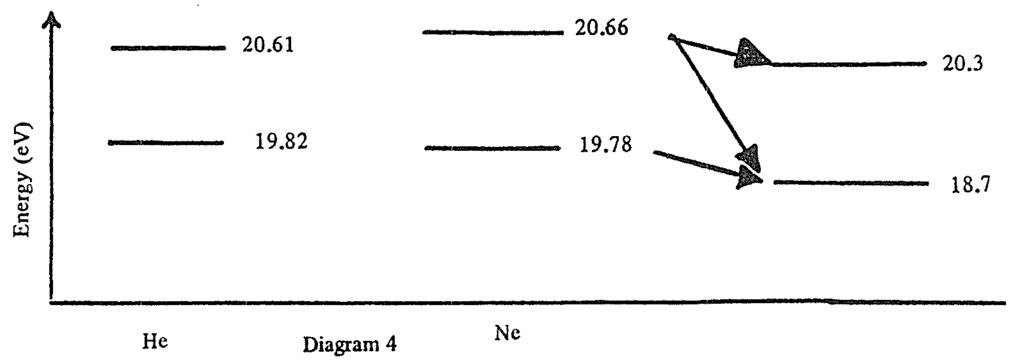


Diagram 4

Excited electrons in the neon may drop to lower energy levels, as indicated in diagram 4, giving rise to three possible radiation frequencies:
a) 20.66eV to 20.3eV (3391nm in the far infrared)
b) 19.78eV to 18.7eV (1152nm in the infrared)
c) 20.66eV to 18.7ev (632.8nm in the visible spectrum)

Any photons of the above wavelengths which are emitted parallel to the axis of the tube will be reflected back and forth between the two end mirrors and as each passes through the tube it gives rise to further identical photons by the process of stimulated emission. This leads to the name LASER, an acronym for Light Amplification by Stimulated Emission of Radiation.

Since one of the mirrors is slightly transmissive some of the coherent, monochromatic light can escape and this is the laser output. Of course each of the three wavelengths is produced. However, the mirrors are designed to attenuate the unwanted wavelengths and allow the wanted wavelength only to be transmitted, in this case 632.8nm.

3. Is a Laser Dangerous to Use?

Yes, it is dangerous, however, provided you observe some simple rules about its use, the danger is minimal.

a) Respect all laser devices as they can cause serious damage. A 1 milliwatt output laser can damage the retina of the human eye.
b) Never look directly down the laser beam or towards the laser part even if the device is not operating. A ping-pong ball provides a reasonably safe cover for an operating laser.
c) Make sure that there are no reflecting surfaces (other than those being used in the experiment) in the area where the laser

is being used. A reflection to the eye is just as bad as the direct beam. Rings, watch bands, glass ware and taps are some examples of reflecting surfaces.

d) Do not use a telescope or binoculars to observe a distant laser.
e) Sun glasses are not sufficient protection even from a low power laser.
f) Protect passers-by by covering all windows and placing signs on all entrances to the room where the laser is operating.
g) Keep the room illumination as high as possible for the particular demonstration or experiment. This keeps the pupil of the eye small and minimises the risk of eye damage.
h) Never leave an operating laser unattended.
i) If the laser is being used outdoors do not track vehicles or aircraft with its beam.
j) Do not operate a laser in rain, snow, fog or heavy dust as potentially dangerous, uncontrolled specular reflection can result.
k) Beware of electrical hazards; the unit operates at about 2000V and contact may be lethal. Do **not** remove the cover and adjust the tube while you have power applied.

4. Does the Laser and Associated Equipment Need Special Storage?

Again a few simple rules will keep your laser in good condition for many years.

a) Do not leave the laser on unnecessarily.
b) Store the unit in a dust free area, as high voltages tend to attract large amounts of dust. A plastic cover would also help in this respect.
c) To prevent corrosion make sure that the storage area is dry and free of chemical stocks.
d) Keep all optical accessories clean and free of fingerprints. If necessary clean lenses and prisms after each use. Wrap the accessories in lens tissue and store in marked envelopes.
e) Never use solvents to clean plastic optical materials.

5. Are There Any Restrictions on the Use of Lasers?

Yes, and it is most important that they are followed. They are for your, as well as the students', protection.

Lasers for school use must have special approval for use if they are not the requisition item. Those available on requisition will not need special approval, but they will be in the low power, continuous visible radiation category. No pulsed laser or laser operating in the infrared or ultraviolet regions of the spectrum or a laser with an output greater than 5 milliwatts will be approved

for use in schools. A member of the science staff at each school where a laser is used is to be designated as the 'laser safety officer'. This officer is to be in sole control of the operation, storage and maintenance of the laser.

The following references will provide further or more detailed information:

1. Electronics Today International, July 1980.
2. Science Notes, Nos. 4,16, 22 and 29.
3. St. George Science Bulletin, No.1, 1981.
4. Circular to Principals, Laser Safety, No. 76/23.
5. Electronics Australia, October 1977.

Note: Diagrams were reproduced and much of the information adapted from Electronics Today International, July 1980. This journal is under copyright. Permission for reproduction has been granted by Electronics Today International.

B. The Laser: Teacher Demonstrations

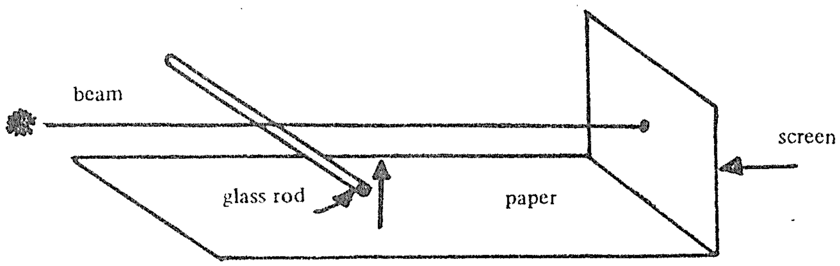
1. Beam intensity can be shown using a 25W opal lamp. About 5% of the 25W goes out as light (i.e. 11/4W). Distributed over the surface of a globe 60mm in diameter gives about 1 400W/m^2 flux. The laser's spot can be seen on the glass showing that the intensity is as great as that of the sun.
2. Monochromaticity may be demonstrated using either a prism or a grating. In neither case is there any appreciable dispersion of light.
3. Divergence is observed by holding graph paper in the beam at various distances from the laser port. The laser's beam diverges much more slowly than light from conventional sources. It is said to be well collimated.
4. Polarisation is also evident in the beam. Rotating a polaroid sheet can extinguish the beam, revealing its near total polarisation.
5. Communication using a laser beam requires a fairly fast photodetector such as a photo transistor. To modulate, vary the discharge current slightly and the intensity of output will vary too. It's just another amplitude modulated signal. (See appendix for a working circuit.)
6. Total Internal Reflection: Dust and air movements prevent long distance communications in air but total internal reflection can be used for near lossless guiding along fibres. Even a stream of water in air will guide light if its path is straight enough.
7. Scattering of coherent light by a finely irregular surface gives rise to a speckled interference pattern over the lit area. No two observers see the same pattern. It is sharp on the retina

irrespective of the eye's focal length because it is an interference phenomenon.

C. The Laser: Student Practicals

1. Producing a Divergent Beam

A divergent beam is so useful that it is the first tool introduced. The usual beam is so narrow that it is difficult to find. A strong lens is needed to produce a significant effect. A piece of 3 or 4mm diameter glass rod is used as a lens to diverge the beam. To observe its effect, place a screen 1/4m in front of the laser and a piece of paper on the bench at its foot as shown below.



Holding the rod horizontally, **raise** it slowly into the beam and then **lower** it again.

What is the effect of the lens?
What danger is associated with taking the rod right through the beam?

Set two more screens (or paper sheets) on either side of the beam. Describe the effect of moving the rod across the beam while held vertically or at some other angle.

How could you find the actual shape of the beam?

N.B. This type of beam will be used in later experiments. When used, set the lens up on a stand, close to the laser source.

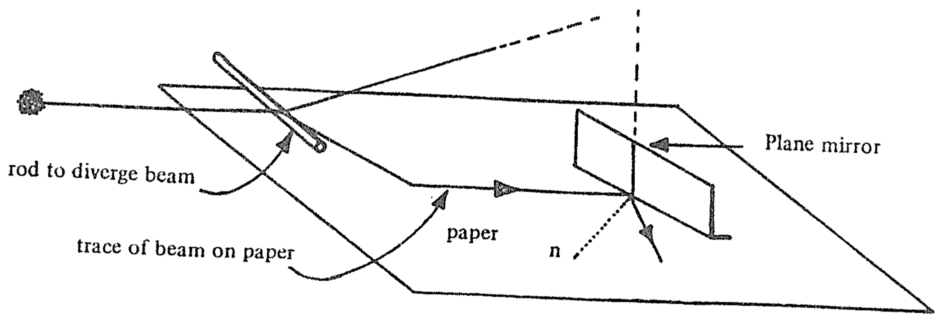
2. The Law of Reflection

In this experiment you should become familiar with the divergent beam while verifying $Ø_i = Ø_r$. The exercise can be done in two ways:

a) showing angles directly with a protractor under the mirror; (see diagram below)

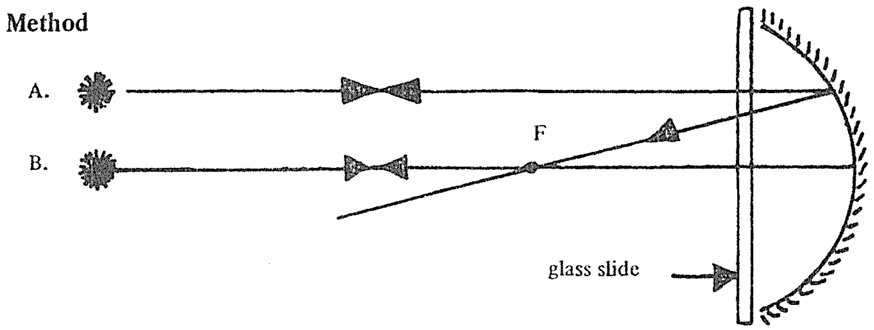
b) by plotting ray paths and mirror positions on paper and checking the angles later.

N.B. Do not forget to place the screens.



3. Radius of Curvature

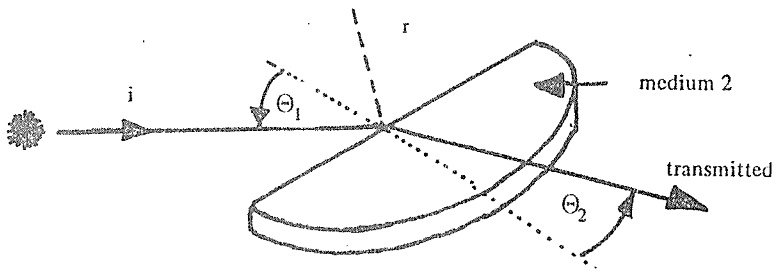
This experiment will allow you to determine the focal length of a shallow cylindrical lens.



The reflection from the glass slide will ensure that the beam is perpendicular and thus the lens is correctly positioned. Move the laser from A to B and **plot the paths of the laser in order to measure the focal length.**

4. Refractive Index of Perspex and Glass

The refractive index N_{12} tells us the relationship between the angles of incidence and transmission at the interface between media in which light travels at differing speeds. It may be found from the ratio of sines of the respective angles, i.e. $N_{12} = \sin \varnothing_1 / \sin \varnothing_2$.



We often speak of the 'refractive index' of glass, perspex, etc. In these cases the other 'medium' implied is a vacuum. Fortunately for us the velocities of light in vacuo and in air are so similar we can neglect the difference and carry on as if we lived in vacuo!

Finding the Refractive Index

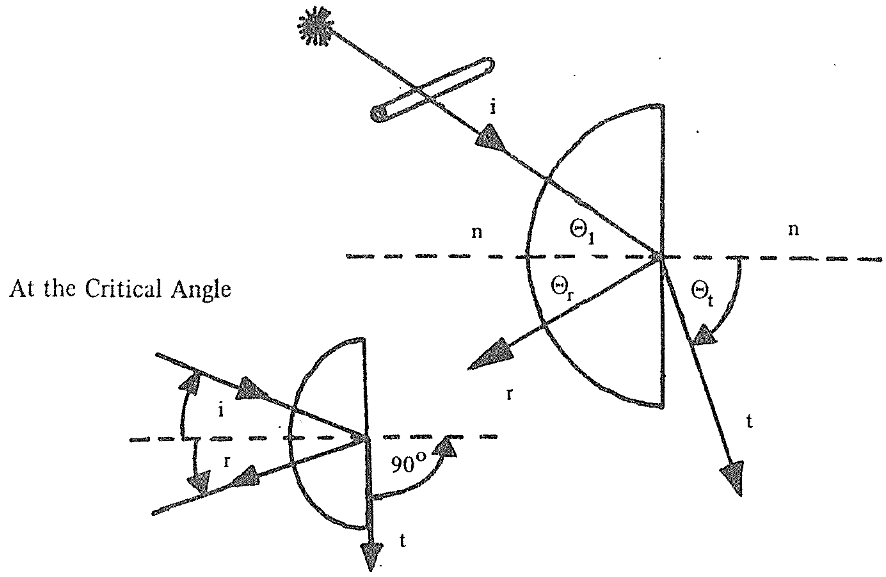
Set up the laser and cylindrical lens to produce the dispersed beam. Allow the beam to follow a sheet of paper on the bench. Place the semi-circular prism so that the light strikes the centre of its straight side.
(How can you check this?) There will now be three rays on your paper. Mark and label them i for incident ray, r for reflected ray and t for transmitted ray. Vary the angle of incidence and find the corresponding angle of reflection.

5. Critical Angle

As might be imagined there is a limit on how far one can bend a beam of light as it passes from a medium of higher refractive index to one of lower refractive index. There is an angle $\varnothing_i$ for which $\varnothing_t$ is 90^0 and no light is transmitted. This value of $\varnothing_i$ is called the critical angle ($\varnothing_{crit}$).
For angles of incidence greater than $\varnothing_{crit}$ there is total (internal) reflection of the incident light.

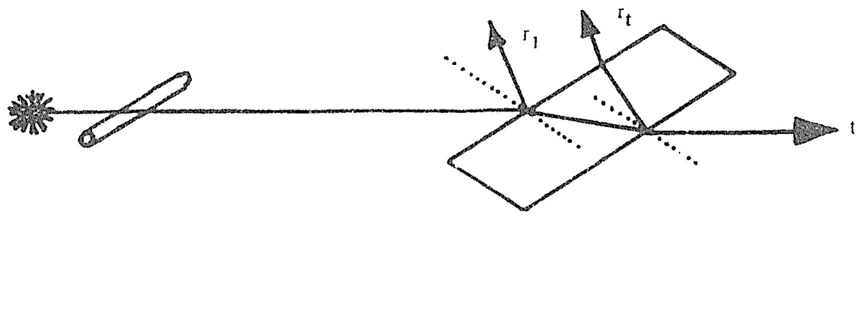
Method
Use the divergent beam again. Lay the perspex D-prism on a sheet of paper in the path of the laser beam, with the curved face nearest the laser. Adjust the prism so that the i-ray is normal to the curved surface and then rotate the prism gently until the t-ray is just extinguished. Mark the paths of i and r. You can use $\varnothing_i - \varnothing_r$ (to avoid having to find the normal). This gives us:

$$\varnothing_{crit} = \frac{\varnothing_i + \varnothing_r}{2}$$



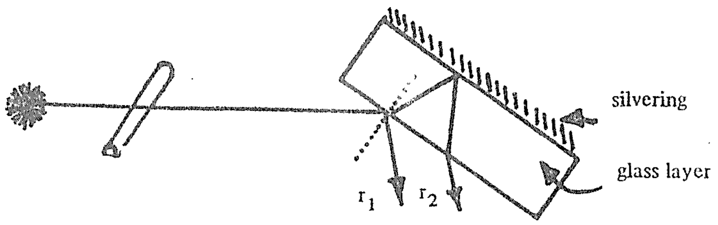
6. Two Methods of Beam Splitting
At any interface there is bound to be some light reflected. With the intense light of a laser this may be of use or a potential hazard.

Set up the laser with its cylinder lens so that a streak appears across a sheet of paper. Place a piece of glass in the beam so that the incident, transmitted and reflected rays may be observed as it is rotated.



Try various thicknesses of glass, using a piece of tape to block off r_2 and various angles of incidence. Compare the intensities of r_1, r_2 and t.

Another non-specialised beam splitter is the second-surface mirror (the kind we use every day).

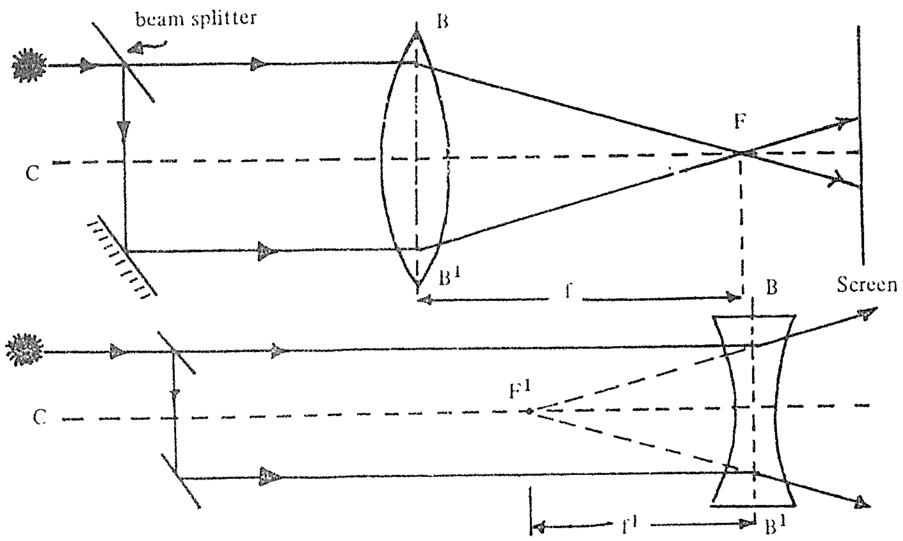


How do the reflected rays behave as the mirror is rotated?
Are they equally intense? Parallel?
Does it compare favourably with the first type?
Can the beam separation be changed easily?

7. Finding the Focal Length Using a Split Beam

This is one of the classical ways of finding the focal length of a lens and hence its power (or dioptre): p = 1/f. Being monochromatic, chromatic aberrations are undetectable, but asphericity is quite easy to detect.

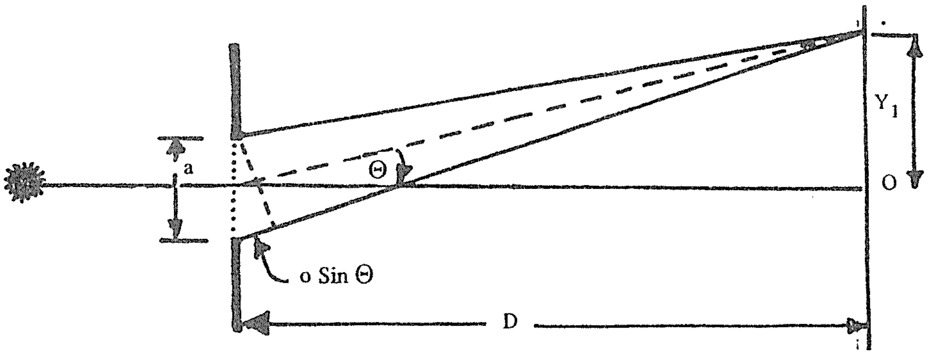
Set up the laser, beamsplitter and mirror to give parallel rays equidistant from a line on a sheet of paper. Set your lens up so that its axis is on the centre line, 'C'.



Apart from the safety screens a small moveable screen is needed for exploring the beam paths. With the convex lens, F may be found directly, but F^1 must be deduced for the concave lens. In both cases the plane BB^1 (at which the incident and transmitted rays intersect) must be deduced from ray plotting before the focal length is found and the power calculated.

8. Measuring the Wavelength of Light - Single Slit

Following Huygens' idea of infinitesimal radiators of circular wave fronts, the criterion for having a maximum intensity at a point, Y, is that there is an integer number of wavelengths' path length difference between Y and the two edges of the slit.



Given a slit 'a' metres wide, D metres from the screen, with D > a and n an integer, then for Y to have a bright spot:

a sin Ø = n¥

For n = 0 the spot lies at 0. This is the transmitted or zero order maximum. The first bright spot caused by diffraction is at Y_1 such that;

¥ = a sin Ø$_1$

Therefore ¥ = a Y_1/D.

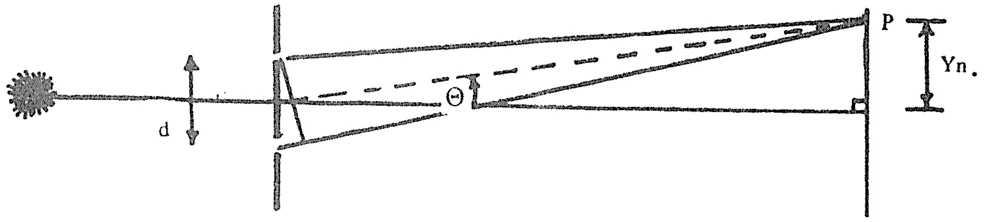
The next, at Y_2 has 2¥ = a Y_2/D, etc.

Since D, Y_1, Y_2 , etc. can be measured this provides a way of finding ¥ providing 'a' is known (or a way of finding 'a' if ¥ is known)

The laser, slit and a screen may be set up as in the diagram to allow the wavelength of the laser's light to be measured.

9. Measuring the Wavelength of Light - Double Slit

For infinitesimally wide slits and a normally incident wavefront, where the slits are d metres apart, ¥ is the wavelength and P lies at an angle of Ø from the normal to the plane of the slits.



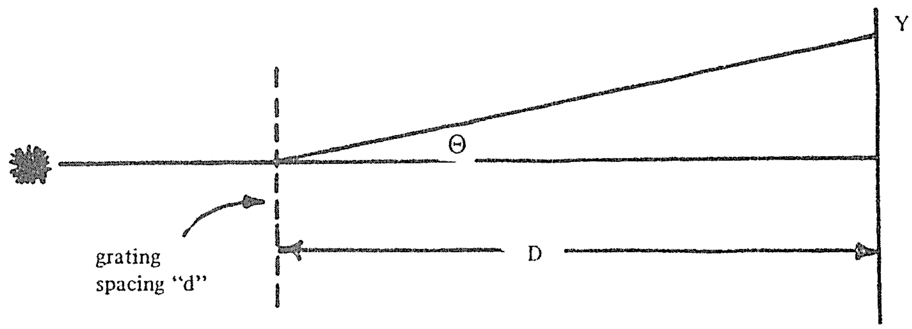
For constructive interference (a bright spot at P) then n¥ = d sinØ where n = 1. 2. 3 etc. If P is Yn metres from the normal and the screen is at D (> d) metres from the slits we can substitute for sinØ to get

$$n¥ = \frac{dYn}{D}$$

Choose a double slit and attempt to measure ¥.

10. **Measuring ¥ Using a Diffraction Grating**

Once again the criterion for constructive interference is that there is a whole number of wavelengths difference in path length from consecutive slits to the screen, i.e. d sin Ø = n¥.



With 'd' very small (≈10µm), this makes for quite large angles Ø so the positions Y_n of maxima at the screen are readily measured. (The grating also passes a lot of light. Three laboratory walls can be used in demonstrations)

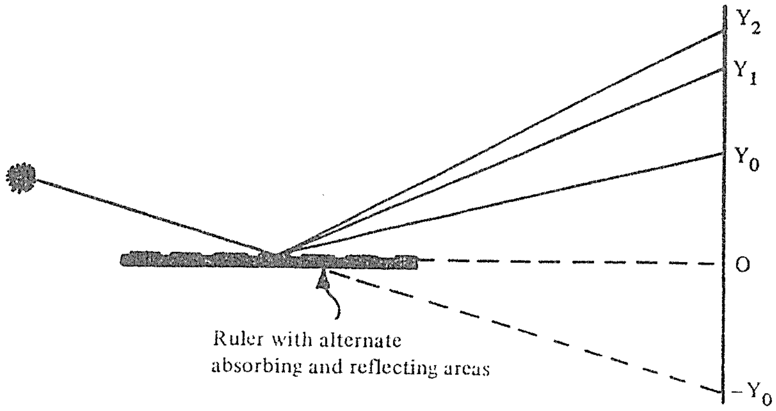
How many orders can you see when the grating, laser and screen are judiciously set up?

Displaying the paths of diffracted rays: pass the diverged beam through the grating and project the beams onto a table.

11. Measuring the Wavelength of Light Using a Steel Ruler

Yes, this has been done. It was first reported in Am. J. Phys. Vol. 33 (Nov. '65) by A.L. Schawlow.

The set up is as simple as in the diagram.



First locate Y_0 with the ruler absent, then move in the ruler so the beam strikes near its end. Y_0 is the position of the specular reflection.
Y_1 is the first maximum, Y_2 is the second.

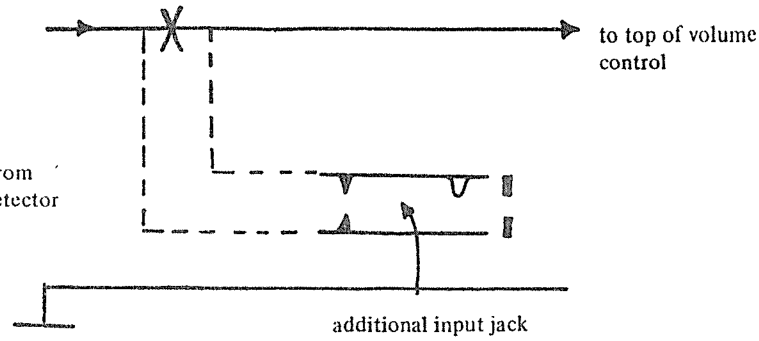
Analysis is complicated by having an angle of incidence, making analysis messy. Schawlow's result is reported as:

$$\lambda = \frac{d}{2n}\,\frac{Y_n^2 - Y_o^2}{D^2}$$

where d is ruling spacing
n is the order
D is the distance, about 2m from ruler to screen
Y_0, Y_n are measured from 0 which is midway between $-Y_0$ and Y_0.

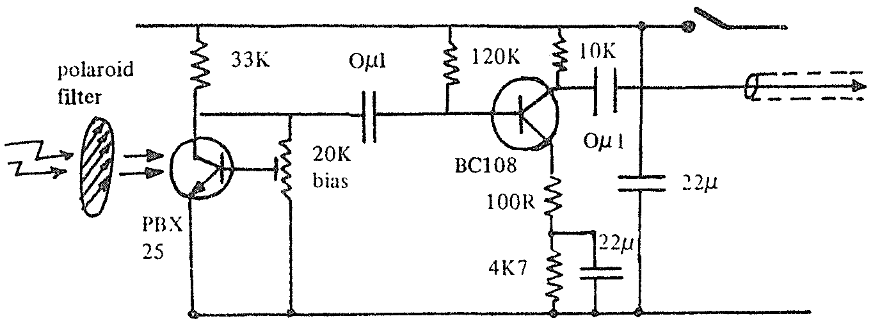
12. Modification of a 'Tranny' for Use as an Amplifier

The easiest way of doing this is to locate the 'top' or clockwise end of the volume control, unsolder its connection, then add in the leads to the new jack. The commonline goes to the bottom of the control. Insulate both well.



13. Photo Transistor and Preamplifier

The polaroid filter may be used to prevent saturation of the transistor when a polarised beam is used (e.g. with a laser).



MULTI-LEVEL PRACTICAL TEST FOR AN ELECTRIC CIRCUITS UNIT, USING A 'BLACK BOX' MAZE (SEN 1982, Vol. 31 No. 4)

Brian Shadwick, Assessment and Evaluation Unit

The apparatus for this practical test has been adapted from similar apparatus used by Robin Gooley, Goulburn HS. Rob has designed a series of 'black box' circuits for use in a Behaviour Unit. In his application, Year 12 students record the number of errors made by Year 7 students as they trace out the live circuit over repeated trials. In this way, the experiment resembles the rat in a maze situation, but allows much more complexity in maze design, including numerous dead-ends.

I have taken the basic idea and adapted it for testing various skills associated with current electricity. Each piece of apparatus can be used to test one simple skill or a string of skills of varying complexity.

Some of the activities a student might be asked to carry out are indicated on the following pages.

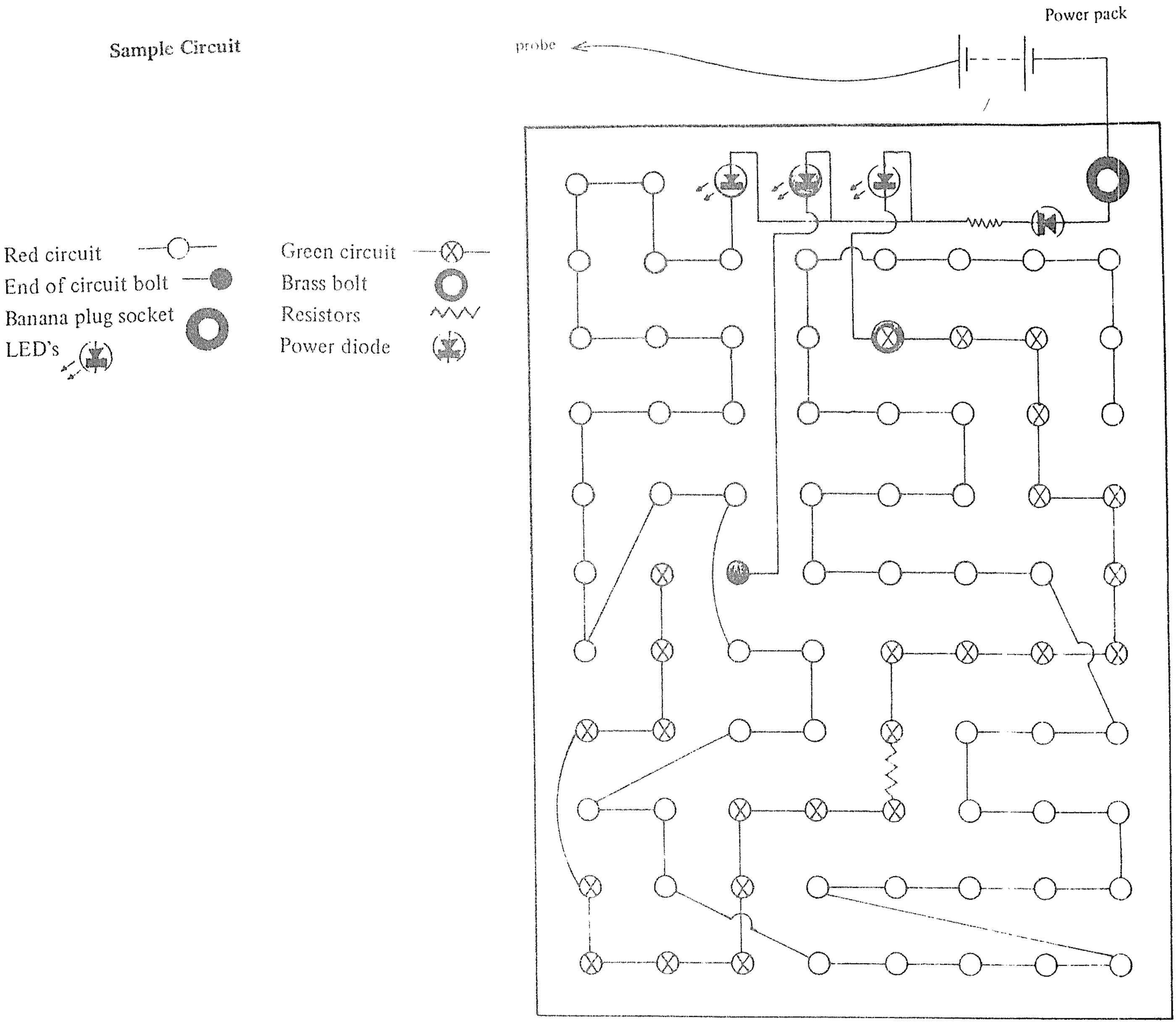
The Apparatus

To construct the apparatus, the following materials were used:

a) 2 pieces of peg-board, 8 holes x 11 holes
b) 1 x 560ohm resistor (to protect LEDs)
c) 1 x 560ohm resistor (as unknown component)
d) 1 x green TIL220R LED (to indicate green circuit)
e) 1 x red TIL220R LED (to indicate incorrect path)
f) 1 x yellow TIL220R LED (to indicate end of circuit)
g) 1 x IN4001 diode (to protect LEDs against a large incorrect polarity in student use)
h) 1 x banana plug socket
i) about 75 x 1.25cm steel nuts and bolts
j) 1 brass nut and bolt (starting point for probing)
k) wire

Approximate cost in Sydney: $2.70.

Sample Circuit



Steps in Construction

1. Cut out 2 pieces of peg-board; paint if you wish.
2. Screw nuts and bolts into top board.
3. Wire green circuit under nuts; include unknown component and brass nut and bolt.
4. Wire incorrect circuit to remaining nuts. (Insulate all crossings.)
5. Connect banana socket, 560ohm resistor, power diode and LEDs to each other as shown in circuit diagram.
6. Connect green circuit to green LED. (Watch polarity.)
7. Connect incorrect circuit to red LED.
8. Connect brass nut to yellow LED.
9. Lay base board over ends of bolts and screw nuts on. Use longer bolts on corners so that the maze bolts will not stick through the holes in the base board.
10. Test circuit. (Use 4 - 6V.)
11. Correct any faults, or make modifications.
12. Write student activity/test cards.

Statistics for Circuit Shown

A. **Green Circuit** - banana plug to brass bolt
For setting G on power pack:
$V = 13V$
$I = 10mA$
$R = 1.3k\Omega$

B. **Green Circuit** - brass bolt to last green bolt
For setting G on power pack:
$V = 13V$
$I = 24.5mA$
$R = 530\Omega$

C. **Red Circuit** - banana plug to any red bolt
For setting G on power pack:
$V = 13V$
$I = 20mA$
$R = 650\Omega$

Using the Apparatus (to trace the green circuit)

1. Connect the positive terminal (red) of the transformer power pack to the banana plug on the peg board.
2. Connect a probe to the negative terminal of the power pack.
3. Turn the power pack to setting G.
4. Start with the probe on the brass screw - the green LED should light up.
5. Moving ORTHOGONALLY ONLY, (left, right, up or down), NOT diagonally, trace the path of the green circuit (green LED).
6. Mark the green circuit on the answer template provided, by colouring in the bolt tops green.
7. If the red LED comes on, you have gone the wrong way. Backtrack to your previous bolt and try another direction.
8. The yellow LED indicates that you have reached the end of the green circuit. Colour this bolt yellow on the answer template.
9. Draw the circuit on the template by connecting the green bolt tops, from the last green bolt.

Option A

1. Use the meters provided to measure the current flowing in the green circuit.
2. Use the meters provided to measure the current flowing in the red circuit.
3. Account for the difference in these currents, if any.

Option B

1. Use the meters provided to measure the resistance of the green circuit.
   Make your measurement between the brass bolt and the last green bolt.
2. Show all calculations.

Option C
A circuit component is hidden somewhere in the green circuit.
a) Find where the component is.
b) Identify what it is.
c) Calculate its value, if any.
d) Complete your green circuit diagram by adding the symbol for this component in its correct position on the template.

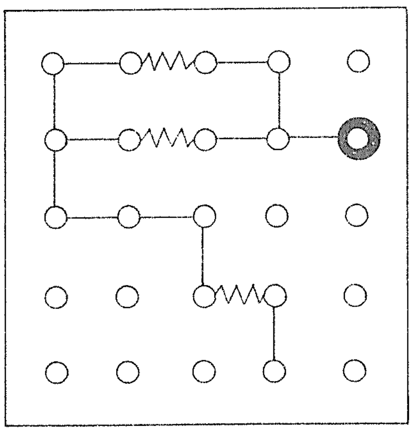
Option D
Use the apparatus provided to determine the position and value of any resistance in the red circuit.

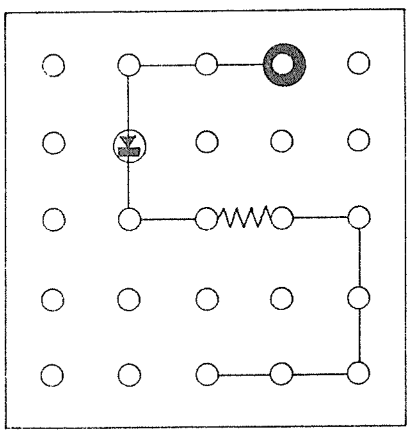
Option E
1. Use the apparatus provided to determine the potential difference between the brass bolt and each other bolt in the green circuit.
2. Tabulate these values.
3. Graph potential difference against bolt number (i.e. bolt 1, bolt 2, 3, 4, etc.)
4. Explain your results.

Option F
The circuit which connects the banana plug socket and the coloured LEDs to the bolts is hidden between the pegboard layer. Design and draw a circuit which would cause the LEDs to work in the way they have.

Further Applications
Obviously 'black boxes' like this can be used in a teaching situation as well as in practical tests. It also has applications in electronics as well as simple circuits.

The 'black boxes' can also be much more simple. Consider, for example, the pieces drawn below.



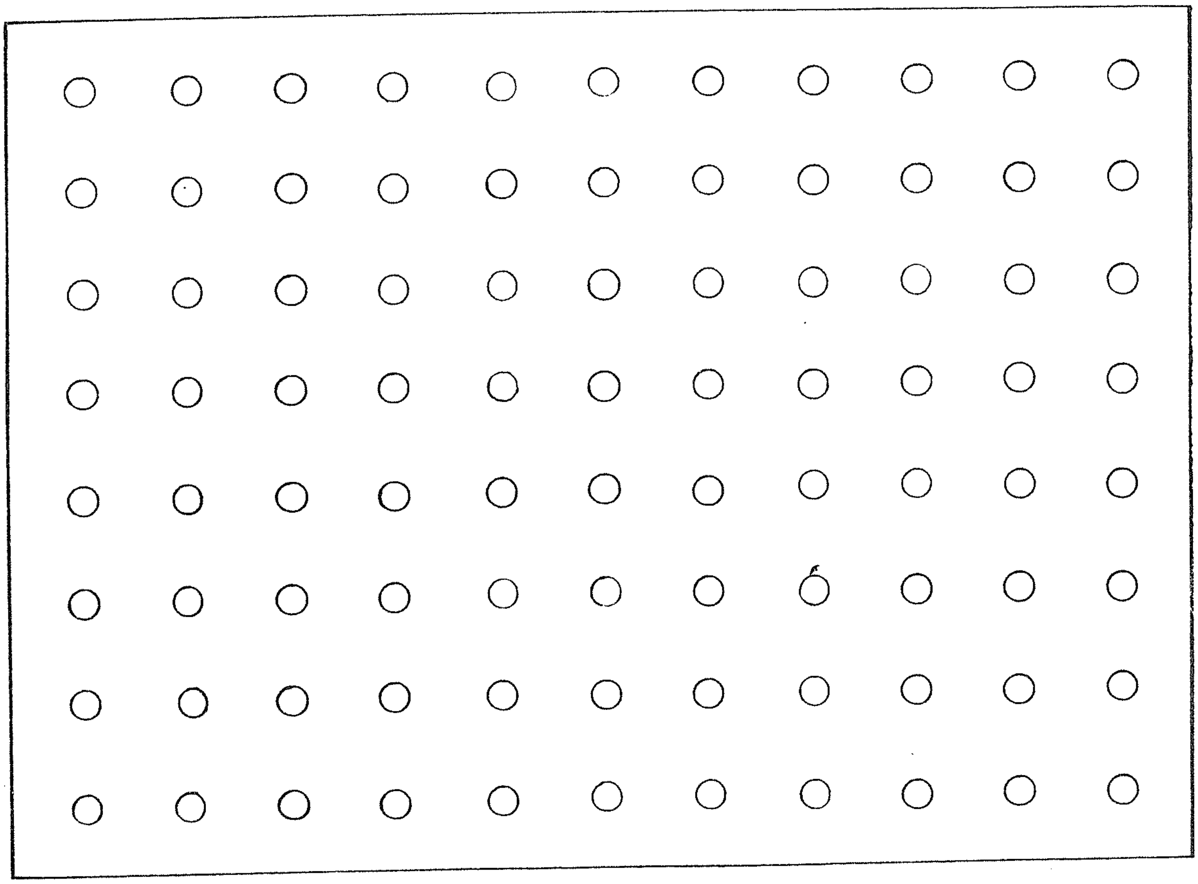


These consist of two pieces of pegboard, each piece 5 holes x 5 holes. Hidden between the pegboard, as before, might be various arrangements of 3 resistors. The following worksheet might be used.

A. The 'black box' contains several resistors in a circuit.
   1. Trace the circuit.
   2. How many resistors are in the hidden circuit?
   3. What are their values?
   4. How are they connected, in series or parallel?
   5. Draw the circuit on the template provided.

Alternatively, students could be given the following.

B. The apparatus contains two hidden components.
   1. Trace the circuit.
   2. Find the positions of the hidden components.
   3. Identify each component.
   4. Determine its value, if relevant.
   5. Draw the circuit on the template provided.



Electric Circuits "Black Box" Answer Template.

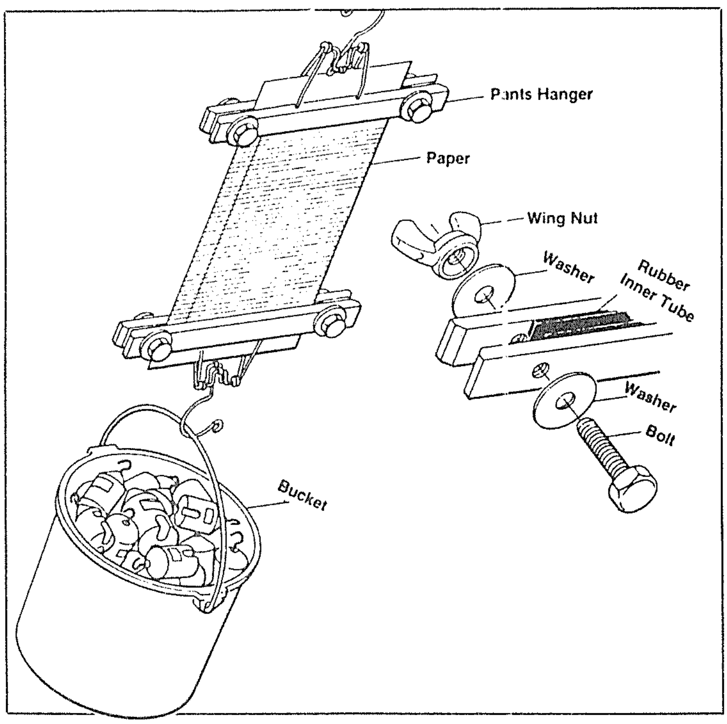
HOW STRONG IS PAPER? (SEN 1982, Vol. 31 No. 4.)
From 'The Science Teacher', March 1982.

Suspend a bucket over a demonstration table with a sheet of paper clamped between two modified pants hangers. (See diagram.) Slowly and carefully add weights, or objects of known mass, to the bucket.

Ask the class, "Who can predict the breaking point of the paper?" Continue to add weights until the bucket is nearly full. It is hoped that students, impressed by the considerable tensile strength of paper, will carry on the test themselves to discover the breaking force.

A dramatic conclusion to the demonstration is to paint a thin line of water across the face of the paper. Most paper under tension, will separate along the water line in a few seconds. Depending on the height of suspension, the crash can be resounding.

Additional Questions which could be asked are:
1. Are two sheets of paper twice as strong as one sheet?
2. Are all types of paper equally strong?



MEASURING MAGNETIC FIELDS USING A HALL EFFECT DEVICE

(SEN 1983, Vol. 32 No. 1)

John Pearce, Chemistry and Physics Department, Melbourne State University

Introduction

Measuring static electric fields has always been a difficult task, particularly in school laboratories. The usual procedure is to measure the deflection of a small compass from magnetic north and after a vector calculation, arrive at a figure showing the relative strength of the field compared to that of the earth. This technique has two points in its favour:

i) the actual technique of comparing two perpendicular vector quantities to obtain relative values is worthy of investigation
ii) the '10 cent' compass is indeed a very sensitive (albeit crude) instrument for indicating field directions (the earth's magnetic field strength is approximately 5×10^5 tesla or gauss).

This article describes a device for measuring magnetic fields directly and with reasonable accuracy. Its principle of operation is the well known Hall Effect enabling detection of magnetic fields as low as 5×10^{-4}T.

Background

If a material (metal or semiconductor) carrying a current I is placed in a transverse magnetic field B, then a magnetic force F_{-m} will act on the current carriers in a direction perpendicular to both I and B (see Figure 1).

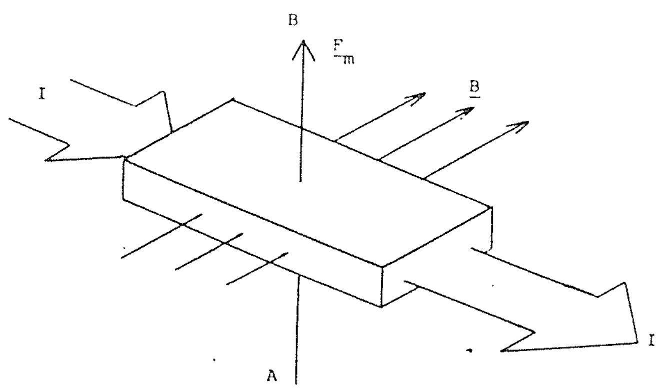


Figure 1

This effect was discovered by E.H. Hall in 1879. The direction of the force is independent of the sign of the charge carriers, hence measuring the resultant induced voltage (V_{AB}) not only indicates the **strength** of the magnetic field, but also the **sign** of the charge carriers. (It is this property of the Hall Effect that enables us to verify that semiconductors can conduct using negative carriers (electrons) or positive carriers (holes) and that the holes act like classical free positive charge carriers.)

Hall Effect devices are found in a variety of applications such as computer terminal keyboards, car ignition systems, speed sensors, proximity sensors, magnetic field detectors, etc.

For our purpose, however, we are interested in a measurement of the Hall Effect voltage, which is proportional to the magnetic field strength that is to be determined.

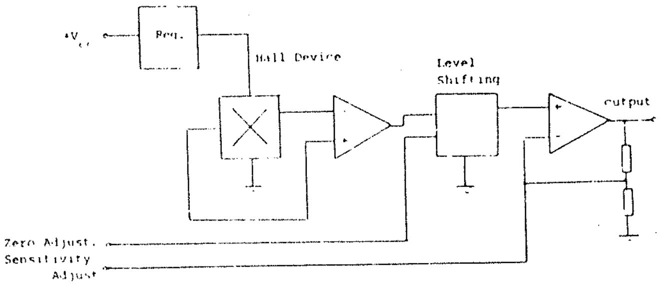


Figure 2.

An Integrated Hall Effect Circuit With Analogue Output

a) Siemens Device SAS231

This is an integrated circuit which incorporates a Hall sensor plus an analogue output amplifier (see Figure 2). The IC contains all the circuitry necessary to output a voltage proportional to an applied magnetic field. However, a few external components are usually required to give control over sensitivity and zero setting. A level shifting circuit is incorporated, enabling an external voltage to determine the output voltage when the field is zero. The IC also contains an operational amplifier whose gain can be altered externally, enabling the sensitivity of the device to be varied.

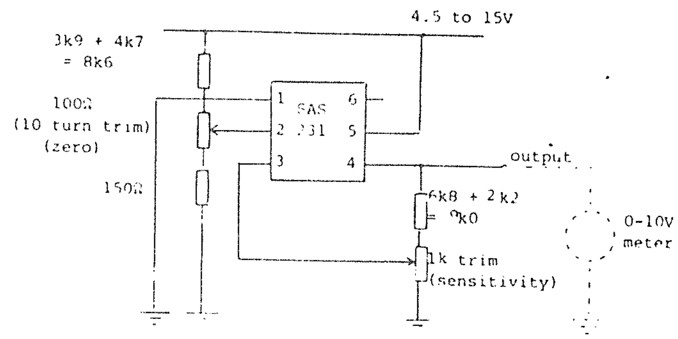


Figure 3

b) Implementing a Circuit to Measure Magnetic Field

Figure 3 shows a complete circuit designed to use the device to measure magnetic fields of the strength typically found around small magnets.

Since the magnetic field must be applied to the IC itself, it is preferable to mount the IC on a small piece of 'veroboard' attached to the end of a probe. The leads from the IC can be terminated on another piece of 'veroboard' holding the four resistors (see photo 1).

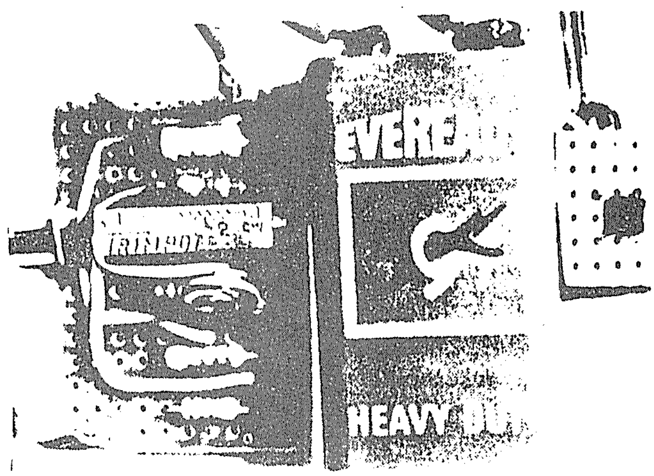


Photo 1

Due to the sensitive nature of the circuit, one of the two potentiometers employed needs to be a '10 turn trim pot' (i.e. 10 turns of the adjustment screw moves the wiper from one extreme

to the other, thus allowing fine adjustments of 'zero'). For normal use, one would set the sensitivity to a convenient setting, then adjust the 'zero' to one half of the supply voltage while no external field is applied. This allows magnetic fields of either sense to be measured. Note, however, that adjusting the sensitivity will affect the zero setting.

c) Calibration

Without calibration, the circuit can be used to compare relative magnetic field strengths. Any change in the output voltage is proportional to the applied magnetic field. The output voltage will saturate at about two volts below the supply voltage.

Calibrating the circuit is simple and a good exercise for students in itself. A PSSC 690 turn air-core solenoid can be used.

Applications

Being able to directly measure field strength opens up many interesting areas of investigation.

Unfortunately, the circuit is not sensitive enough to detect the field around a single current carrying wire. Even with a current of 10amps, the field at 1cm is about 0.2mT. This corresponds to a deflection of less than 0.2volts from the zero and would become lost in the drift of the signal. (It makes one appreciate how sensitive those '10 cent' compasses really are!)

An obvious area where such a device can be used is in plotting the magnetic field around a magnet or coil. An added advantage here is that students can actually obtain a numerical value for the field a magnet produces at a given distance. How many students currently could say whether a 'typical' bar magnet produces a field of10^{4}T, 1T or 10^{-4}T at one of its poles?

Alternating fields can be observed with the aid of an oscilloscope. This has application in electromagnetic induction, 'leakage' from a transformer, etc., used to provide a uniform, predictable field given by the expression:

$B = u_0 n I$

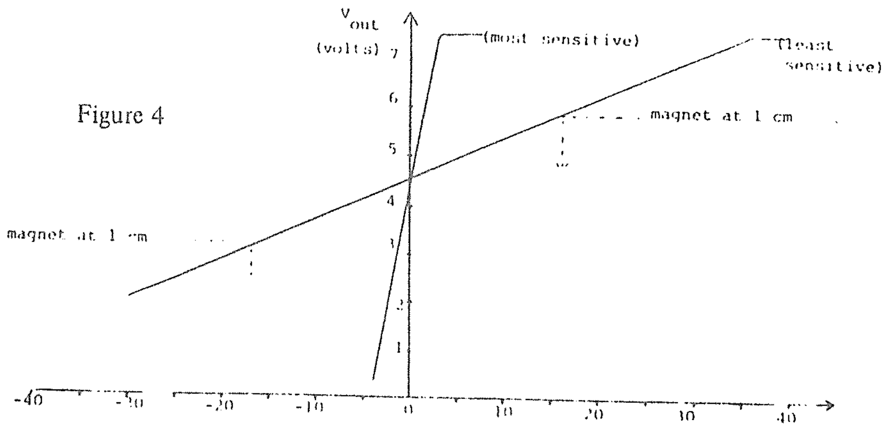
where	u_0	=	magnetic permeability of free space
	n	=	number of turns per unit length
and	I	=	current.

Substituting the values:

we get	u_0	=	$4\pi \times 10^{-7}$ TmA^{-1}
	n	=	$690/0.149$ m^{-1}
and	B/I	=	5.8×10^{-3} TA^{-1}

Calibrating graphs for the device set at each extreme of sensitivity are shown in Figure 4.

Figure 4



MAGNETIC FIELD

Shown on one of the graphs is the response to a typical school bar magnet held 1cm from the probe. (Approx. 0.02 T or 220 Gauss).

The sensitivity ranges from about

70mV/mT to 930mV/mT

(0.40mV/mA) (5.4mV/mA)

(The air core solenoid will carry up to 7amps for **short** times.)

Conclusion

For about $8.00 and an hour or so of time, a device can be made to extend students' ability to probe the physical world. The simplicity of the circuit and relatively low cost makes it a useful alternative method for measuring magnetic fields.

References

U. Lachmann, SAS 231, An Integrated Hall Effect Circuit with Analogue Output, Components Report XIV (1979) No. 6 SAS 231

available from: Systems Reliability Australia Pty. Ltd.,
(Syncom)
49 Tope Street,
South Melbourne. 699 8433.

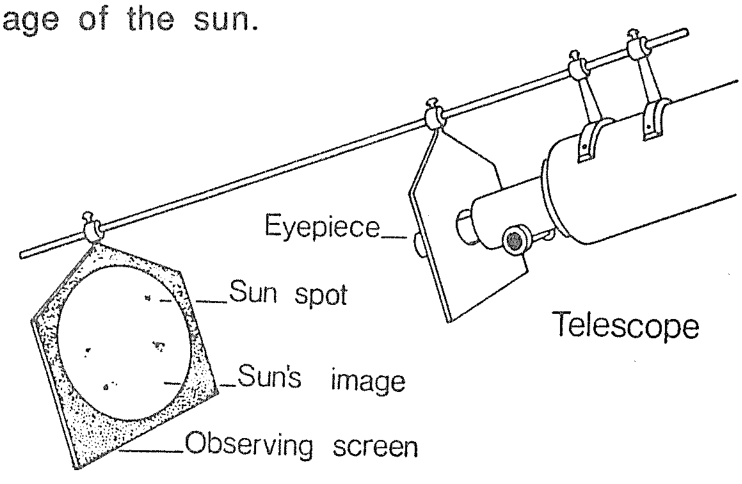
OBSERVING THE SUN (SEN 1983, Vol. 32 No. 2)
Jeff Ryder, Curator, Brisbane Planetarium

Watching the sun is a fun astronomy project that students can try during school hours. All that is needed is a small telescope and a smooth white card. If your school or the school board science consultant cannot come up with a telescope ask your students. Small astronomical telescopes are becoming quite common.

Caution: The eye can be blinded or injured by a direct look at the sun with a telescope. Warn your students never to look directly at the sun with or without a telescope. The sun-filters sold with many small telescopes are unsafe. Besides only one person at a time can look.

The safe, simple way to observe the sun is to use the telescope to project its image onto a white card as shown in the diagram. Many fancy gizmos are sold to hold a projection card in place on the telescope, but hand holding it or taping it to a chair works fine.

Point the telescope towards the sun by watching its shadow. When it casts a perfectly round shadow it is pointed correctly. Then hold the card about a foot behind the telescope's eyepiece. A little fine tuning with the focusing knobs and some minor adjustments in pointing the telescope should turn the bright fuzzy blob on the card into a crisp image of the sun. Try poking a hole in a piece of cardboard and placing it over the telescope tube to cast a pool of shade around the projected image of the sun.



This diagram shows one simple set-up for projecting the sun's image. Some telescopes use a mirror or a prism to project the image off to one side, rather than directly behind the eyepiece as shown here. If your telescope has a small finder, cap it or cover the lens with cardboard and tape before pointing the telescope at the sun.

Reprinted from STAQ Newsletter, No. 9, December 1982

ADDITIONAL EXPERIMENT ON POLARISATION OF LIGHT FOR ELECTIVE 2 - WAVE NATURE OF LIGHT (SEN 1983, Vol. 32 No. 2)
Alan Smith, Tempe HS

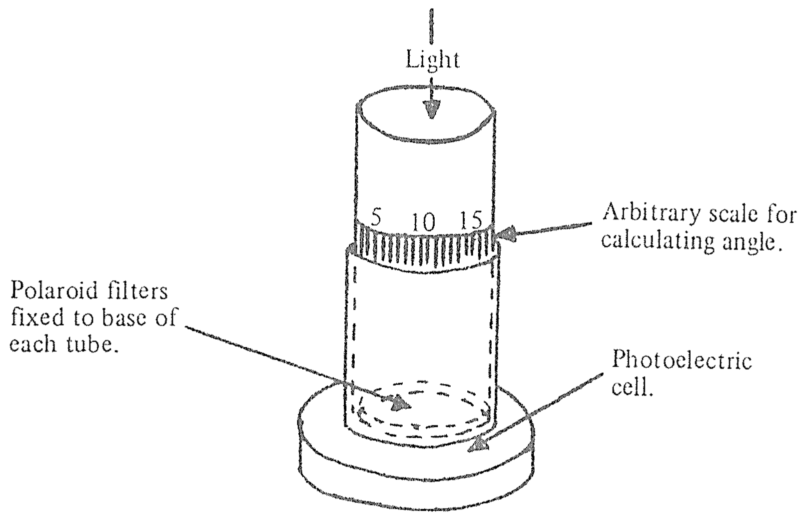
Some of the available resources, Fundamentals of Physics and PSSC, do not have a practical suitable to demonstrate the relationship $I = I_0 \cos^2\phi$ listed in the syllabus as being suitable for mathematical treatment.

This demonstration can be made from materials in the PSSC optical kit, or, if need be from sunglass lenses and cardboard tubing. The following demonstration has been used successfully with Year 12 students.

Aim: To show that light passing through two polarising filters placed at an angle ϕ to one another is given by:

$I = I_0 \cos^2\phi$ where I_0 = incident intensity
and I = resultant intensity

Method: Two polaroid filters were fixed into tubes which were then placed onto a photoelectric cell of a 'Lux' meter, as shown in the diagram.



An arbitrary scale was attached to the inside tube (Graph Paper) which had a total of 77 divisions to cover 360°.

THUS: $1 \text{ Division} = \frac{1}{77} \times 360^\circ$

$= 4.67^\circ$

STEP 1: Find the position so that the light intensity is a maximum, i.e. polaroids are parallel.

An arbitrary scale was attached to the inside of the tube (graph paper) which had a total of 77 divisions to cover 360^0.

$$\text{Thus 1 division} = \frac{1}{77} \times 360^0$$
$$= 4.67^0$$

Step 1 Find the position so that the light intensity is a maximum, i.e. polaroids are parallel.
Step 2 Adjust illumination to maximise scale deflection.
Step 3 Record division number and light intensity, then repeat at regular intervals for at least 90^0.

Angle and Intensity
Sample Result

	ANGLE		RADIATION INTENSITY
'POSITION'	'ANGLE IN		'ANGLE IN
'LUX'			
	DIVISIONS'	DEGREES'	
56.5	0	0	490
60.0	3.5	16.4	440
62.5	6.0	28.0	380
65.0	8.5	39.7	280
67.5	11.0	51.4	180
70.0	13.5	63.1	90
72.5	16.0	74.8	25
75.0	18.5	86.5	5
77.0	21.5	100.5	15

CALCULATIONS

To show that $I = I_0 \cos^2 ø$ we could:

i) plot I v. $\cos^2 ø$ since I_0 is constant
ii) calculate $I_0 = \dfrac{I}{\cos^2 ø}$ I should be a constant for all values of I and Ø
iii) calculate some other constant such as $K = \dfrac{I_0 \cos^2 ø}{I}$

We shall use $I_0 = \dfrac{I}{\cos^2 ø}$

TABLE OF CALCULATED VALUES

ANGLE Ø (deg)	$Cos^2Ø$	I	$I_0 = I/cos^2ø$
0	1	490	490
16.4	0.92	440	478
28.0	0.78	380	487
39.7	0.59	280	472
51.4	0.39	180	462
63.1	0.20	90	440
74.8	0.07	25	364
86.5	$3.7x10^{-3}$	5	1341
100.5	0.03	15	452

All of the calculations for I_o in column 4 should have the same value. Why would you expect angles approaching 90^0 to produce greater variations (errors)?

Conclusion: These results indicate that the calculated values of I_0 are within reasonable agreement with I_0 at 90^0. Thus we may state: $I = I_0cos^2ø$

You should now perform a similar experiment with refinements such as:
* fix the external tube in position (use clamp)
* correct I value by subtracting background radiation at given angle
* change intensity so more accurate values are taken as ø approaches 90^0 (difficult).

Questions
1. Rewrite this demonstration fully as an experiment, showing Aim, Method, etc., showing the theory of light which is applicable to polarisation and how $I = I_0cos^2ø$ is arrived at and an appreciation for the errors involved in any calculations. (You need not take multiple readings.)
2. How would you check that the photoelectric cell has a linear relation to intensity of the incident light?

Editor's Note
For those with a 'spread sheet calculator' program like 'visicalc' the entire result and calculation table would be relatively easy to program.

USING A LASER AND PLASTIC FIBRES TO TRANSMIT SPEECH

(SEN 1983, Vol. 32 No. 4)

Karl Becker and Benildus Ng, Christian Brothers' College, Sutherland

Introduction

Few science teachers, or students, will be unaware of the recent advances in using optical fibres for telecommunications. The basic principle of fibre optics, internal reflection of light, is easily understood and just as easily demonstrated, using traditional optics kits. The 1 milliwatt helium-neon lasers, now available to school science departments, make possible an exciting demonstration of the way lasers can be used to transmit speech through glass or plastic fibres.

While the focus of attention in the demonstration outlined below is on the use made of fibre optics for telecommunications and thus pertinent to a topic such as Communications, there are many facets of the demonstration to which the focus could be shifted if required. For example, the focus could be on diffraction for a Year 11 or 12 Physics class dealing with the Wave Properties of Light, or yet again on the photosensitive transistor and amplification for a Year 11 or 12 Physics class dealing with the Electronics elective. Depending on the focus of attention, various aspects of the working apparatus can be treated as 'black boxes' so as not to distract students from the point being demonstrated.

Background and General Procedure

Figure 1 below shows the general outline of the equipment required for the demonstration.

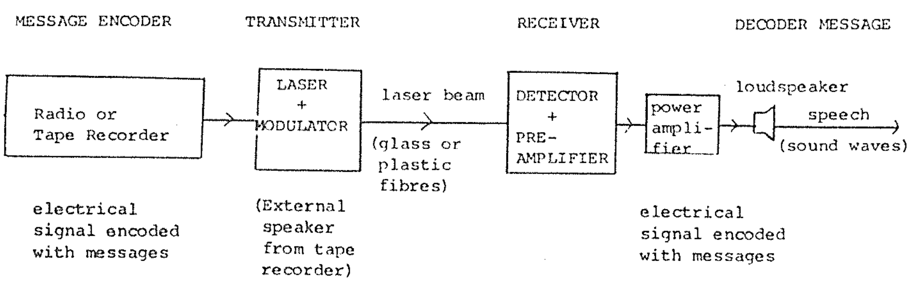


Figure 1: A laser communication system

Message Encoder (Tape Recorder)

We have found it simplest to use a radio or tape recorder connected to an external speaker. If the teacher wishes to have students' voices transmitted 'live', then it is understood that the voice signal should be amplified before applying it to the speaker.

Transmitter (Laser plus Modulator)
Modulation is performed mechanically by a pinhole moving across a fixed laser beam. This, of course, is a relatively crude way of modulating the laser beam, but one which is easily performed, easily understood and can actually be seen by students. Figure 2 shows the modulator. It consists simply of a small piece of copper sheet (about 2 x 1cm) glued to the centre of a small speaker. The laser is directed at a pinhole in the copper sheet. As the speaker cone vibrates up and down according to the pressure variations of the (electrical) voice signal there will be a corresponding shifting of the whole diffraction pattern of the beam emerging from the pinhole. If the central maximum has initially been directed onto the plastic fibre(s) and hence to the light sensitive transistor, then the shifting of the diffraction pattern will result in a variation of the intensity of the light received by the phototransistor in accordance with the voice.

Actually, the edge of the copper sheet rather than the pinhole can be used to modulate the laser's intensity. Though the quality of sound produced is not so good, this method does eliminate the need for any discussion of diffraction with junior classes.

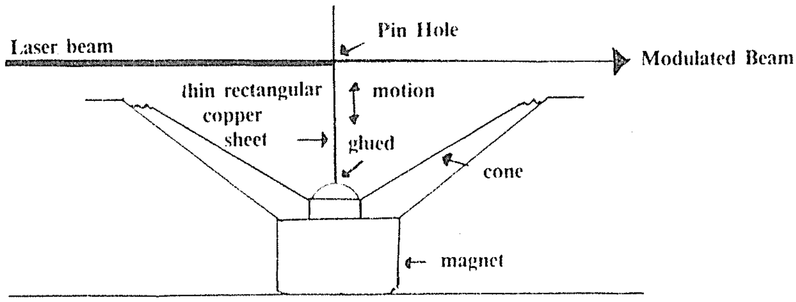


Figure 2: Pin Hole Modulator

Channel (plastic fibres)
These can be used singly or in bundles. Obviously, the demonstration is a more forceful one if the fibres are coiled or bent, as this is their advantage. They are easily and cheaply obtainable from electronic stores. If thin glass tubing is substituted, a length not more than 20cm is recommended as the glass absorbs too much light. It is possible, of course, to do the whole demonstration without the fibres. In this case the channel is air and the demonstration can be one of radiowave modulation and transmission. Indeed, the whole apparatus can be set up firstly without the fibres and these inserted later.

Receiver (Detector and Preamplifier)

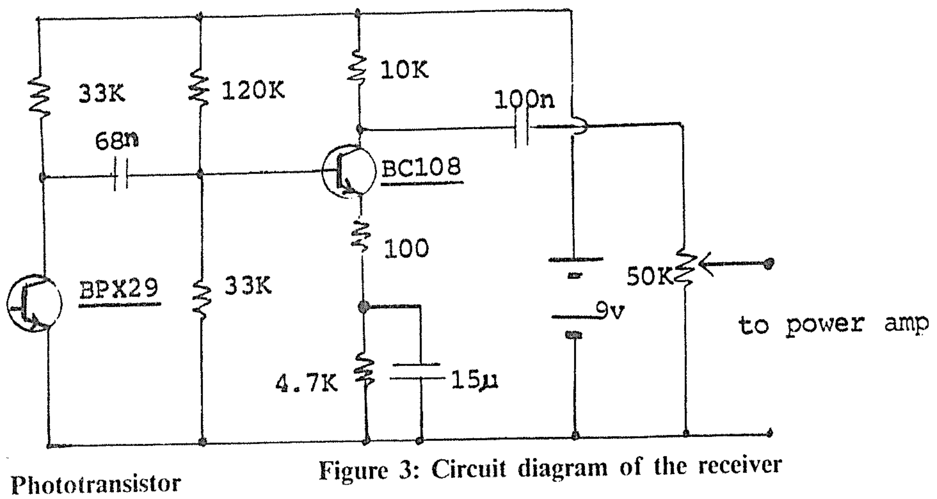


Figure 3: Circuit diagram of the receiver

Figure 3 shows the circuit diagram for the detector and preamplifier. This, of course, has to be made prior to the demonstration. Electronics buffs - and every school has them - love making such modules! It is suggested that this module be covered with cardboard with a hole for the laser to strike the photo transistor. This is to avoid stray laser reflections off exposed metals during the setting up. When monochromatic light strikes a photo transistor it produces an output current proportional to the intensity of the incident light. Thus, as the central maximum of the diffraction pattern shifts position according to the pressure variations of the speaker carrying the modulator, so the intensity of light striking the photo transistor will be similarly modulated. (c.f. Figure 4.) The output current is then amplified by the second transistor.

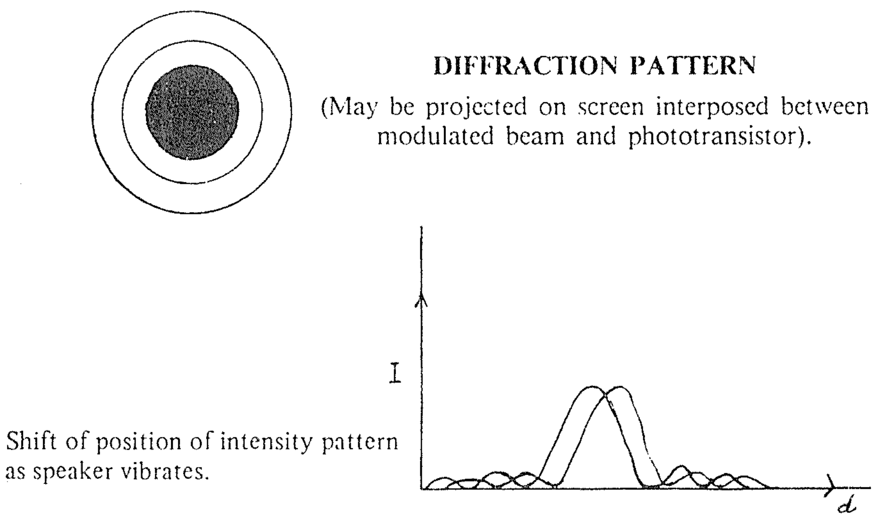


Figure 4

Decoder Message.
Any suitable amplifier can be used. The one used with the Microwave Kit is ideal as it has the speaker and amplifier in one unit. The sound received is quite a reasonable reproduction. Clarity can be improved by fine adjustments of:

a) the laser light striking the photo transistor
b) the variable resistor in the receiver circuit
c) the volume control of the radio or tape recorder used

The range of frequencies which are detected can be checked by substituting an audio-oscillator for the radio and a CRO for the decoder speaker. A frequency range of 300 to 3kHz is quite reasonable for essentially distorted sound reproduction.

General Notes

1. This demonstration is not intended just for teachers who are electronics or laser buffs. Detailed knowledge of electronic circuitry is not required. The usual safety precautions are to be taken, of course, when using the laser.
2. Each sub-unit can be tested independently of the other part before putting them all together.
3. The smaller the pinhole used, the larger the diffraction pattern. This increases the modulation received. If transmission is through air this diffraction pattern also determines the range of transmission, but with fibres the range is not affected by altering the pinhole size.
4. Two problems which thinking students commonly raise regarding the use of fibres involve:
   i) loss of intensity if fibres are very long
   ii) interference effects as different paths are followed by different light rays in a single fibre

Technology already has answers to these problems. Optical fibres can now be made so that they absorb the same amount of light in 150 metres that would be absorbed by a centimetre of window pane glass.

The ingenious solution to the second problem was to make fibres in such a way that the refractive index decreased from the centre outwards. A rate of variation can be chosen so that a zig-zagging ray arrives at the same time as a ray travelling straight through the centre.

Conclusion

Provided the sub-units are pretested, this demonstration is one which is relatively foolproof as well as being as exciting one for teachers and students alike. The sub-units, once made, can be stored and the experiment repeated indefinitely with relatively little time consuming preparation for each demonstration.

References

Student Projects in Physical Sciences, Vol. 6, University of NSW, 1982.

The Promise of Optical Communications, Brochure issued by Telecom Australia, September, 1979.

THE MICROWAVE KIT AND LASER (SEN 1983, Vol. 32 No. 4)
Kevin Molyneux, Cabramatta HS

A What are microwaves?

The term microwave stems from the fact that these electomagnetic waves have a wavelength of about 10^{-6} (or micro) of the wavelength of radio waves. Thus, with a wavelength of about a few centimetres, microwaves lie between radio waves and infra-red radiation on the electomagnetic spectrum and overlap these two to some extent.

B. What does the kit consist of?

For a cost of $250 on the 1984 requisition, you get a transmitter, a horn detector, two large metal plates, one small metal plate, a large solid wax lens, a lens holder, a large solid wax prism, a polarising grill and a large plastic plate.
You must supply 2 power packs and an audioamplifier.

C. What can you do with the kit?

You can demonstrate almost any wave phenomenon you like with it. Usually, the major problem is setting the kit up and keeping it in working order. (So what's new?)

1. Setting up the equipment
   * Connect the transmitter to the power pack. (12V AC)
   * Connect the receiver to the audioamplifier.
     (**N.B. Most Important.** Do **NOT connect** the receiver directly to the power pack. This is a major cause of breakdown of the kit.)
   * Connect the audioamplifier to the power pack.
   * Place the transmitter and receiver about 1 metre apart and switch on; if everything is alright you should be able to control the sound at the audioamplifier.
2. Penetration of different materials, e.g. metal plates, plastic, wax.
3. Reflection, e.g. around a barrier using the metal plate as a mirror.
4. Refraction, e.g. through the wax lens.
5. Total internal reflection, through the wax prism.
6. Diffraction, through the slit formed by the two metal plates.
7. Interference, through the two slits formed by the two large metal plates and the smaller metal plate between them.
8. Polarisation, using the grills vertically and horizontally, or turning the receiver through 90^{0}.

D. Where in science programs could the kit be used?

Obviously in senior Physics the kit finds the greatest application in showing the wave phenomena of electromagnetic radiation and can be used as an alternative, an addition, or a prelude to wave properties of light.

However, it is my contention that it can also find use in the junior course. For example, the kit might find use in the main content area Number 3, in the section on Obtaining and Using Energy. The kit could be used to demonstrate the idea of transmitter and receiver in radio; it could be used to show differences between sound and radio waves; and it could supplement studies of light to show similar properties for radio waves.

E. References

Not many of these are around, but perhaps the best is 'Fundamentals of Senior Physics' by Parham R. and Webber B., Lab. Manual No. 2, published by Heinemann, 1972. Experiment 5.12.

The Laser

A. Points to note before buying or using the laser

* The laser, an acronym derived from Light Amplification by Stimulated Emission of Radiation, will cost you $328 on the 1984 requisition.
* Your school must appoint a Laser Safety officer (usually the Science Head Teacher or a Physics teacher) who must supervise its use and be satisfied that anyone using it knows how to use it safely.
* Laser light can cause blindness by retinal burning. Thus it is vital that nobody looks directly into the tube or a reflection from a mirror or bright surface.
* Doors must be locked and safety signs displayed when the laser is in operation.

B. What can you do with the laser?

As with the micro-wave kit, one can demonstrate many phenomena similar to light and thus find use for it in senior Physics.
However, I contend that it can also find use in the junior course in much of the same content areas as the microwave kit.

* Seeing the beam; scatter chalk dust along the beam.
* Reflection; use a plain mirror or more than one and again scatter chalk dust.
* Refraction; pass the beam through a large beaker of water.
* Total internal reflection; use the same beaker of water.
* Scattering the beam; use a clear piece of ice.

* Other experiments; these could include the laws of reflection, using a prism to show the monochromatic nature of laser light; determining the critical angle for water/air interface, etc. Once you start using the laser it is surprising how many experiments you can devise yourself.

C. References

1. For safety practices and regulations for schools, refer first to the Memorandum to schools dated 26th September 1983 on 'Safe Use of Lasers in Schools'.
2. The above memorandum replaces 76/23 on the 'Use of Lasers in Schools'
3. Information can also be obtained from Science Notes Numbers 23 and 29.
4. A useful little booklet from Metropolitan South West Region is called 'Information on the Use of Lasers in Schools'.
5. Scientific American, August 1980.
6. 'Lasers', SEN, 1982, Vol. 31, No. 1. This is a most useful and comprehensive treatment of the use of the laser.

CIRCULAR MOTION ON AN INCLINED TRACK (SEN 1983, Vol. 32 No. 4)
Alan Smith, Tempe HS

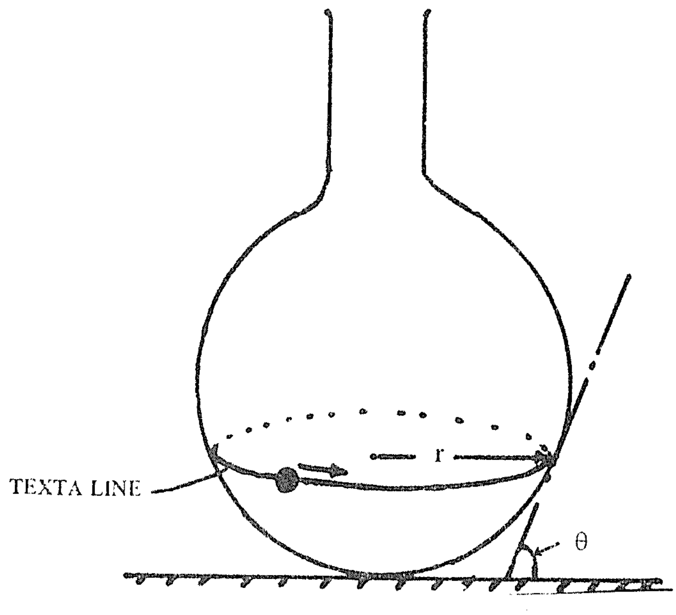
Here is a simple method of treating motion in a circle on an inclined plane. If care is taken with small round bottomed flasks (up to 500mL), results to within 5% of the expected value can be achieved by students. A 1 litre round bottomed flask works very well indeed.

Aim: To verify that the derived equation for subjects travelling about an inclined track obey the relationship:

$$\text{Tan } \varnothing = \frac{v^2}{gr} \quad - (1)$$

Method:

1. Take a large round bottomed flask and draw a circle about its base (using texta). (See diagram below.)
2. Place a small ball bearing in the flask and start it rotating along the line drawn on the flask.
3. Time an appropriate number of revolutions of the ball bearing to calculate the period T.
4. Measure the tangential angle of the texta line with the horizontal.



Sample Calculations

The following measurements were taken in class.

$\phi = 68^0$

$r = 5cm$

time for 10 revolutions = 3.73secs

Calculate velocity V, using equation 1 and from the period of revolution.

a) $\tan \phi = \frac{v^2}{gr}$

$\therefore v^2 = gr \tan \phi$

$= 9.8 \times 5 \times 10^{-2} \tan 68^0$

$= 0.67 \ ms^{-1}$

b) Period $T = \frac{3.73}{10} = 0.3735$

$v = \frac{s}{t} = \frac{2\pi r}{T}$

$= \frac{2\pi \ 5 \times 10^{-2}}{0.373}$

$= 0.85 \ ms^{-1}$

A TWO SLIT INTERFERENCE EXPERIMENT (SEN 1984, Vol. 33 No. 1)
Colin Gauld, School of Education, University of NSW

When two patches of light combine on a screen to give areas of darkness the advantage of a wave model of light over the classical particle model is clearly demonstrated. The easiest way to show this to a class is to use a laser but a simple two slit interference experiment allows students to handle the equipment and to measure the wavelength of the light for themselves.

There are two versions of this experiment. In the most commonly described (and most easily carried out) form, the student looks through the two slits towards the light source and sees a pattern of dark and light bands of differing widths and intensities (Ref 1). However the nature of the pattern is not immediately obvious. The bands appear to be located somewhere near to the light source rather than on the screen and it may not be clear to the student that the normal explanation for the two slit interference applies in this case.

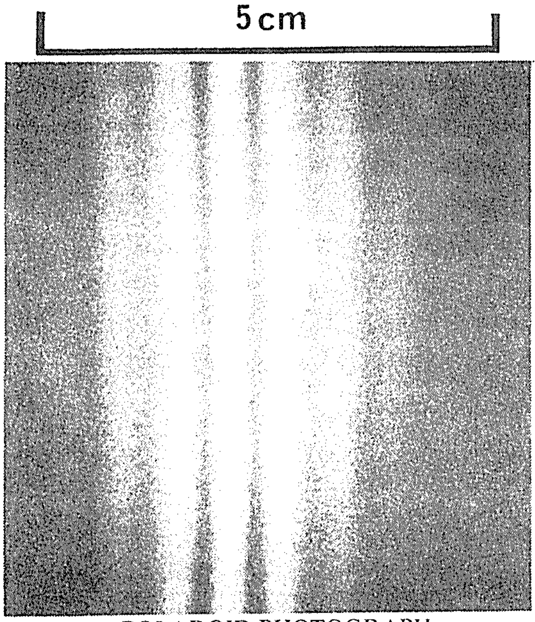
In the other form of the experiment the light from the two slits is allowed to fall on to a screen where the pattern can be seen (Ref 2). In this version the role of interference is more easily understood and so is more satisfactory for use with students than the one described above.

The following experiment is a modification of that found in the Nuffield O-Level Physics course. One of its features is the production of a full sized Polaroid (or 35mm) photograph of the interference pattern for later use (see Figure 2). The experiment can be carried out in an ordinary, darkened laboratory and does not require specialised equipment.

The Experiment

Figure 2 shows the apparatus required for the experiment and how it should be arranged. The components and the steps in the procedure are described below.

1. Twelve volt, 5 amp power supply.
2. Twelve volt (about 40 watt) straight filament car headlamp. (Alternatively one filament of an appropriate double filament lamp can be used.) The filament is lined up to be parallel to the slits on the slide (see 3). A reasonably large cardboard box (or other suitable cover) with a small opening at the front should be used to prevent unwanted light emerging from the lamp.



POLAROID PHOTOGRAPH
OF INTERFERENCE FRINGES
FIGURE 1

3. Microscope slide covered with carbon from alcoholic Aquadag. The coating should be neither too thick nor too thin. Slits are scribed with a pin and a straight edge so that they are;
   a) not too thin or else not enough light will get through
   b) not too thick or you won't see the fringes
   c) not too far apart or the fringes will be too close together
   d) as close as possible while still leaving a black strip between them.

   A number of pairs of slits are drawn on the one slide and the best one chosen for the experiment. To prevent scratching the carbon coated side is then covered with a second, clear microscope slide taped to the first at each end. Alternatively, a specially prepared photographic negative (homemade or commercially produced) can be used.
4. An opaque screen to eliminate light reflected off the top of the desk below the slits.
5. Screen made from fine-grained tracing paper stuck on a cardboard frame. To be seen most clearly the fringes should be viewed from the back of the screen.

Photographing the Fringes with a Polaroid Camera

6. Supplementary lens with the same focal length as the camera lens. This is taped over the front of the camera. The distance between the supplementary lens and the screen should be equal to the focal length of the supplementary lens (Ref. 3).
7. Polaroid camera focuses on infinity and with the aperture opened as wide as possible (e.g. by using the colour setting) the electric eye is covered up when the picture is taken. The exposure is found by trial and error. For the fringes in Figure 1 the exposure was 60 seconds. If the supplementary lens and the camera lens do not have the same focal length the picture will either be a reduced or an enlarged representation of the fringes.

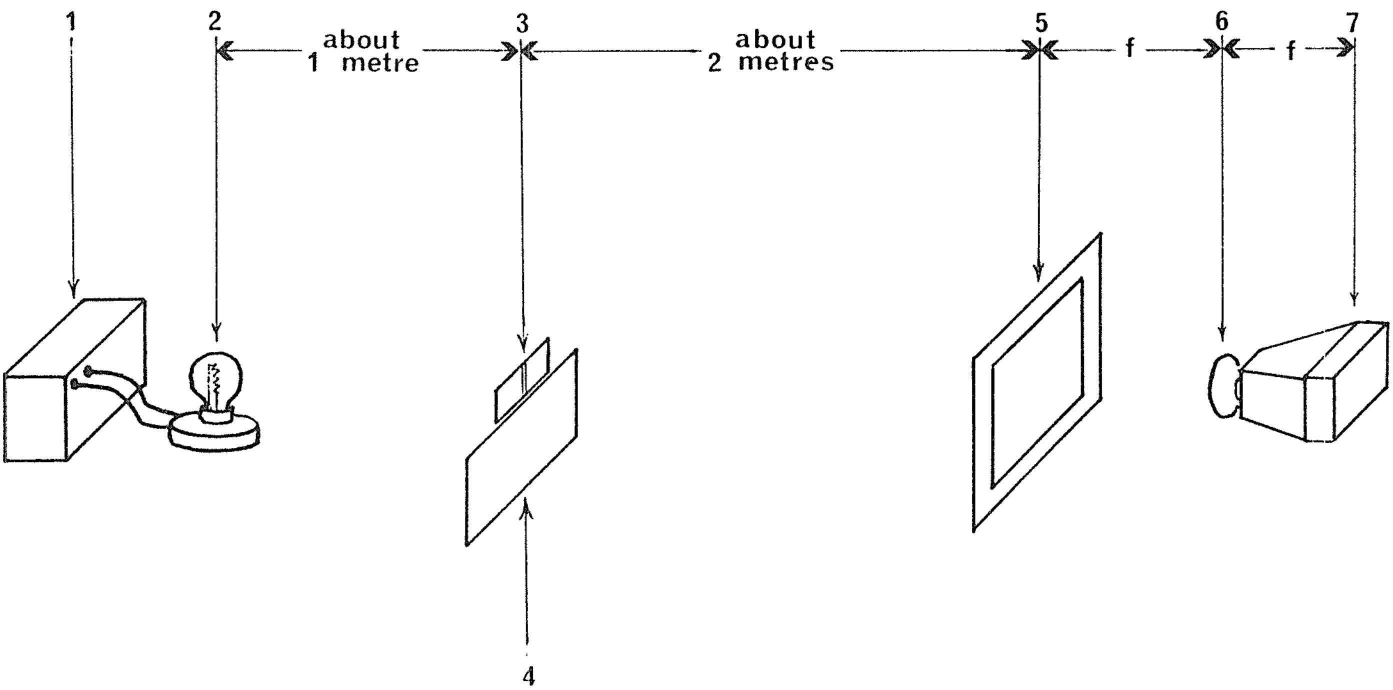


FIGURE 2 THE LAYOUT OF THE EQUIPMENT

Measuring the Wavelength of Light

Measure the distance (D) between the slits and the screen with a metre rule. Measure the average distance (F) between the neighbouring dark fringes of the screen or the photograph.

To measure the distance between the slits remove the slide carrier from a slide projector. Place a transparent ruler with a scale marked in millimetres in the position where the slide would be and focus an image on a white board or projector screen. Measure the average magnified distance between adjacent millimetre marks and calculate the magnification factor of the projector. Without adjusting the projector at all, replace the ruler with the microscope slide backwards or forwards. Measure the average distance between the centres of the magnified images of the two slits and use the magnification factor to calculate the actual distance between the slits (a).

The average wavelength of the light is calculated using the formula wavelength = aF/D. For the fringes shown in Figure 1
a = 0.22mm, D = 2.010m and f = 6.33mm. Thus

$$\text{Average wavelength of white light} = \frac{af}{D} = \frac{2.2 \times 10^{-4} \times 6.3 \times 10^{-3}}{2.01}$$

$$= 6.9 \times 10^{-7}\text{m}$$

References

1. Gardner, E.D. & White R.T. *Practical Physics*, McGraw-Hill, Sydney, 1972, 67-69.
   Lehmann, R.L. & Swartz, C. *Foundations of Physics: Laboratory Experiments,* Holt, Rinehard & Winston, New York, 1969, 133.
2. Nuffield Foundation, *Nuffield Physics: Guide to Experiment 3,* Longmans/Penguin, London, 1967, 160-163.
   Tai, A. & Boydell S. *A Guide to Year 11 Practical Physics,* Sorrett, Malvern, 1981, 160-162.
3. Hodgins, R. 'Some Ideas about Close Up Photography', *Australian Science Teachers Journal,* 16 (1), May 1970, 95-100.

VOICE TRANSMISSION ON A LIGHT BEAM (SEN 1984, Vol. 33 No. 1)

Ray Ceccato, Wade HS, Griffith

The article by Karl Becker and Benildus Ng in the November issue of SEN, 1983 prompted me to dig out an old circuit which performs a similar task without the need for a laser.

The circuit is based on an article in Transistor Projects Volume 2, a Radio Shack publication, 1974, It consists of a light beam transmitter (a modified transistor radio) and a simple light beam receiver.

For convenience's sake the Tandy Catalogue numbers have been included in the parts list. However, equivalent types should be suitable.

Transmitter Equipment

1 small transistor radio or tape recorder with **transformer output**
1 222 lamp (272-1124)
1 11/2V cell
Disconnect the speaker and connect the following circuit (Figure 1).

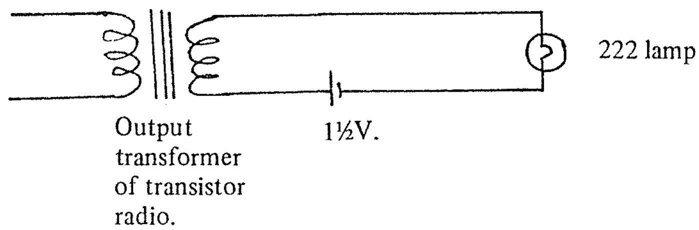


FIGURE 1

The 11/2 V cell provides a base level of illumination. When tuned to a radio station the audio signal modulates the lamp. This causes the lamp to flicker. The modulated light output is detected by a photosensitive receiver circuit (Figure 3) and converted back to an audio signal.

The following modification, (Figure 2), enables the radio to be tuned via the speaker and then switched to the light beam output.

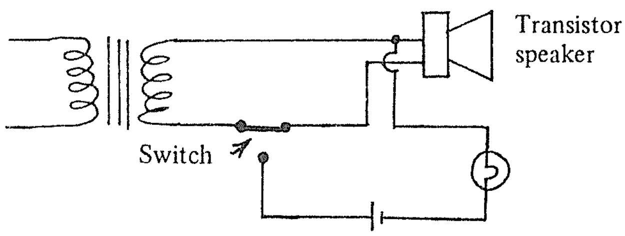


FIGURE 2

Receiver Equipment
1 9V battery
1 capacitor 0.1 uF
1 resistor 10 KΩ
1 resistor 240KΩ
T1 photoresistor FPT - 100 (276-130)
T2 PNP transistor 2N2907 (276-2021)
1 miniature transistor earphone (33-175)
The receiving circuit is simple and straightforward to build (Figure 3).

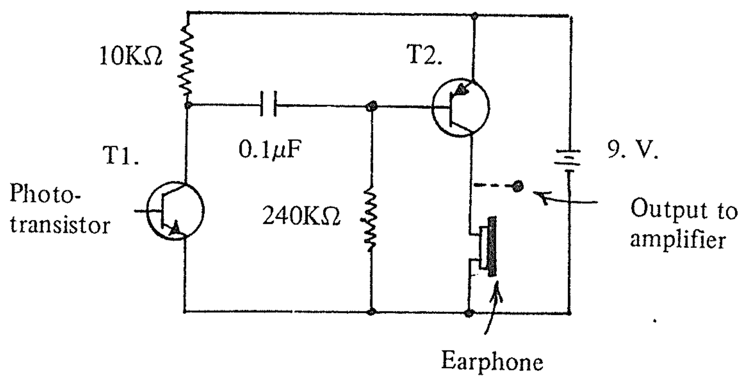


FIGURE 3

The modulated lamp output is allowed to fall on the phototransistor and the audio signal is heard in the earphone. A sheet of paper can be used to interrupt the light beam to show that optical coupling is being achieved (Figure 4).

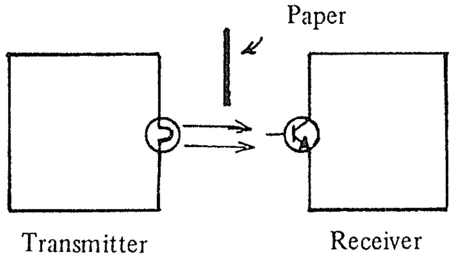


FIGURE 4

The circuit performs well. However, the range is limited to 15-20cm due to the diverging light beam. The optical coupling could be improved by the use of optical fibres as described by Becker and Ng, or by the use of suitable lenses and reflectors.

Output from the receiving unit can be easily amplified for class listening by connecting the SRDU audio amplifier across the earphone or across T2.

Points to Experiment With

1. Vary the base illumination of the lamp by using 3V battery and various combinations of 10Ω resistors
2. Try 2KΩ headphones in place of the earphone
3. Replace the earphone with a 5KΩ-10KΩ resistor and try a crystal earpiece in parallel

References

Mims, F.M. *Transistor Projects.* Volume 2, Radio Shack 1974

Mims, F.M. Optoelectronic Projects. Volume 1, Radio Shack 1976

Becker, K and Ng, B. Using a Laser and Plastic Fibres to Transmit Speech. SEN 1983, Vol. 32 No. 4.

HYDROELECTRIC GENERATOR (SEN 1984, Vol. 33 No. 4)
N.E. Austen, Leichhardt HS

This generator will drive lights, 6V tape recorder, 6V radio with suppressor, low voltage electric motor. With increasing load current, audible reduction of turbine revolution rate is heard, a useful demonstration for senior physics as well.

Materials

* 200g coffee can with press-fit lid, 100mm diameter x 120mm high, for turbine
* 1 extra lid from 200g coffee can for turbine pulley
* 1 gallon paint can, 180mm diameter x 190mm high, for turbine housing
* Tin-plate for turbine vanes, escapement and pulley back
* Brass rod for turbine axle, 4mm diameter x 270mm long
* 1/2 inch OD copper tube, 40mm long, for water inlet
* Copper tube for turbine axle bearings

Figure 1. Turbine Vanes

a. Cut 4 pieces of rectangular tin-plate 40mm x 116mm
b. Fold 10mm x 1160mm flap on each vane for soldering to coffee can

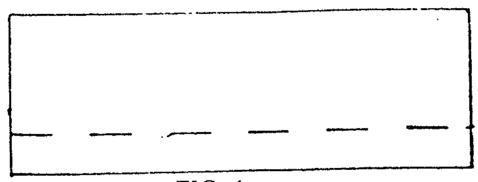


FIG. 1.

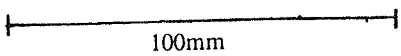


Figure 2. Turbine

a. Find and pierce centres in base and lid of coffee can. (Graph paper can be used to find the centre of a circle.)
b. Mark position of turbine vanes on coffee can, separated by 90^0 of arc.
c. Solder 10mm x 116mm flap of each vane fully to coffee can at marked positions.
d. Enlarge centre holes of lid and base of can outwards to accept the 4mm diameter brass axle rod, 270mm long.
e. Insert axle through lid to allow 30mm to protrude outwards.
f. Insert axle through can base and firmly close lid.
g. Completely solder lid in place.
h. Solder axle firmly to can at both ends.
i. Slide brass connector onto axle and position about 85mm from end.

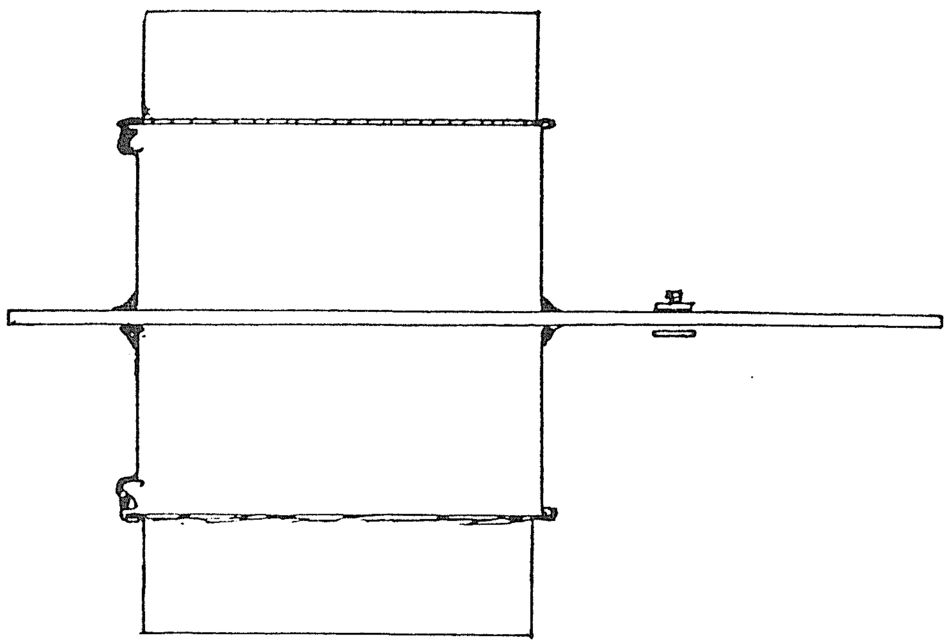


FIG. 2.

Figure 3. Turbine Housing

a. Find and pierce centres in lid and base of paint can.
b. Mark 120mm x 70mm escapement on side of paint can as shown.
c. Cut along solid lines of escapement.
d. Fold outwards along dotted lines to form two flaps for soldering escapement.
e. Construct rectangular escapement from a 200mm x 50mm tinplate strip.
f. Solder escapement to can and prepared flaps. (See Figure 7 for e. and f.)
g. Enlarge hole in paint can base to accept bearing for turbine axle.
h. Solder bearing to base of can.
i. Solder axle bearing to inside of paint can lid. Do NOT enlarge hole in lid as the lid is the axle end stop. The small hole is an oil hole.

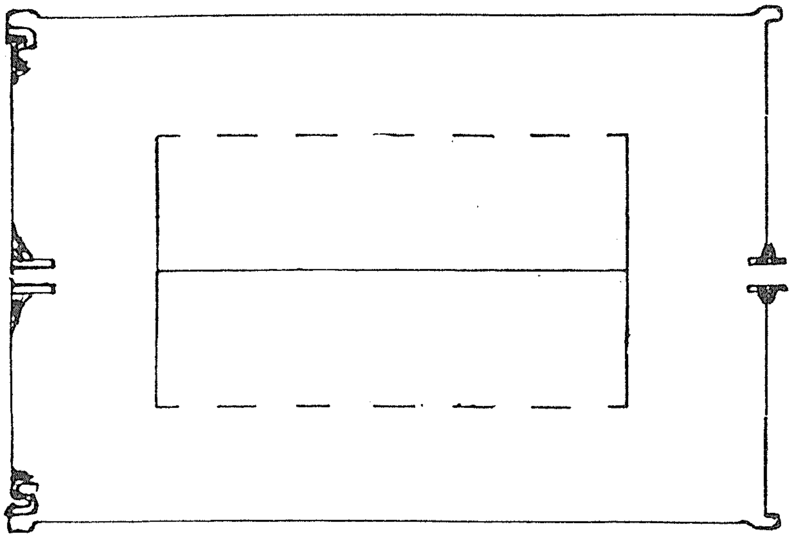


FIG. 3.

Figure 4. Turbine Pulley

a. Cut 89mm tinplate disc.
b. Fully solder disc to spare coffee tin lid to form turbine axle pulleys.
c. Find and pierce lid centre and enlarge hole to accept turbine axle. Do not solder to axle.

FIG. 4.

Figure 5. Water Inlet Tube

a. Cut 40mm of 1/2 inch OD copper tube.
b. Bell end to accept 1/2 inch hose.
c. Flatten other end to form fan jet.

FIG. 5.

Figures 6 and 7

a. Pierce paint can from inside to accept fanned end of water inlet.
b. Solder inlet tube in place.
c. Check end-play of turbine axle, adjusting axle stop as required.
d. Solder turbine pulley to turbine axle.
e. Clamp completed unit to suitable base-board.
f. Fasten suitable 6V motor to base-board.
g. Fit motor with suitable pulley to act as retainer for belt.
h. Fit 3 or 4 suitable rubber bands to turbine pulley and axle of motor.
i. Attach motor leads to 4mm sockets marked for polarity.

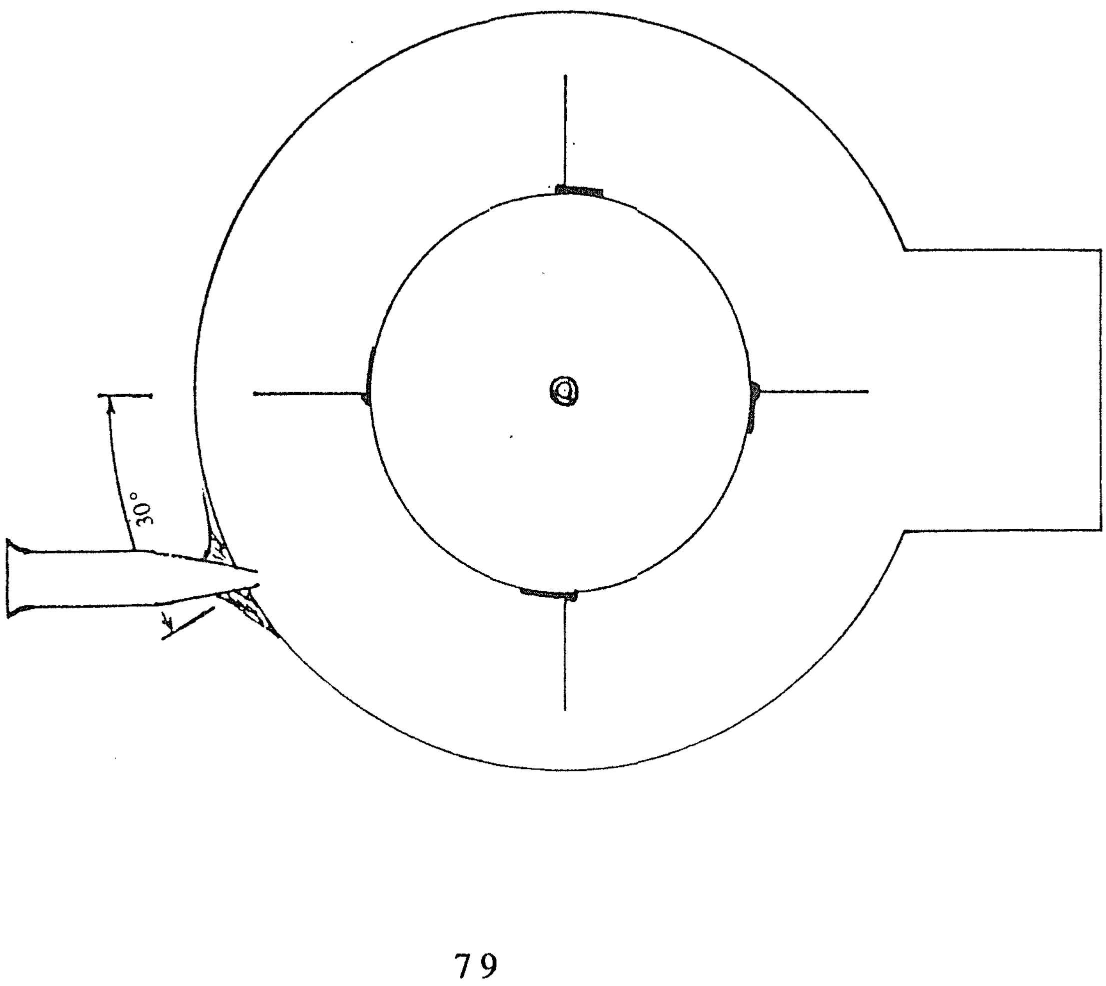


FIG. 6.

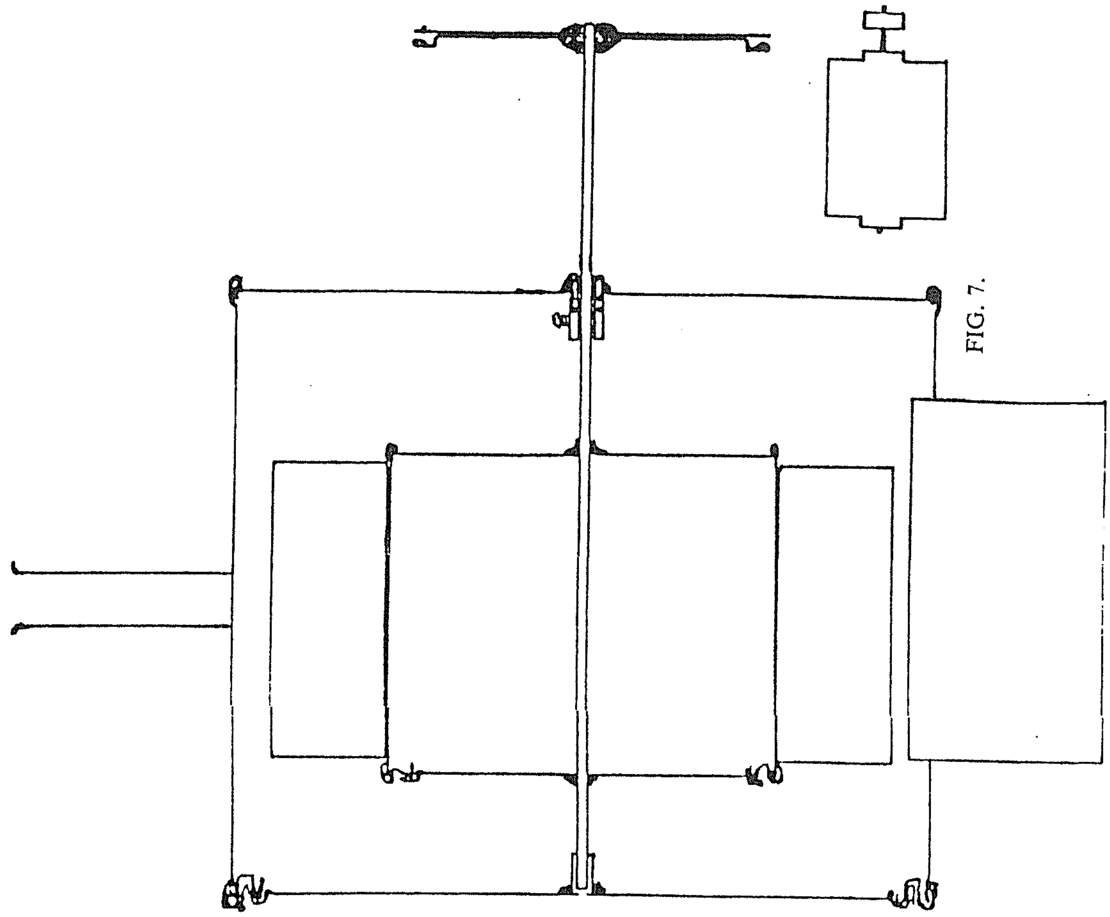


FIG. 7.

PROJECTILE MOTION (SEN 1984, Vol. 33 No. 4)
George Kelen

Aim
To give meaning to and an alternative description of projectile motion.

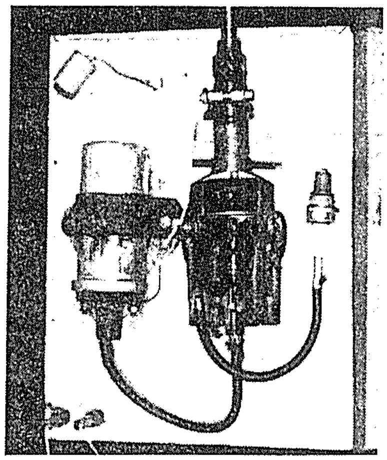
Method
1. Get the following equipment.
   * 1 retort stand with bosshead and clamp
   * 1 cardboard protractor (about 450mm diameter)
   * 1 measuring tape
   * 1 garden hose and nozzle
   * sticky tape
   * a metre rule
2. * Fix hose nozzle to give a steady stream
   * Put protractor onto stand by pushing the clamp through the centre of the baseline before attaching the clamp to the bosshead. Tape the top of the protractor to the stand at the 90^0 mark
   * Put the nozzle into the clamp and set it at 30^0
   * Turn on the tap
   * Describe the path of the water
   * Measure the distance from the end of the nozzle to where the water hits the ground
   * Estimate the height of the stream above the ground
   * Turn the tap on slightly more than before and repeat the last two steps
   * Repeat for three more adjustments of the tap
   (It is hoped that students can deduce that for fixed angle, the distance travelled is directly proportional to the velocity.)
3. * Put the nozzle at 0^0
   * Turn on the tap
   * Measure horizontal and vertical displacements. (Run the hose near a wall.)
   * Increase the angle by 10^0
   * Repeat the measurements
   * Keep increasing the angle and the measuremants, up to 70^0
   (It is hoped that the students are able to see that, for a fixed velocity, the horizontal distance is a function of the initial angle (but there is a limit) and the vertical distance is increased with an increase in the initial angle.)
4. Return the nozzle to 45^0 to see if this gives the maximum horizontal for the same velocity as in part 3

The major problem with this experiment is the tendency of the stream to separate.

RECYCLED CAR PARTS IN THE PHYSICS LABORATORY
(SEN 1985, Vol. 34 No. 3)
Herbert Simpendorfer, St Paul's College, Walla Walla

In our modern throw away society, cars are junked with many of the component parts in them still in excellent, serviceable condition. These parts are well made and worth a lot of money, yet they are to be found in many official and some unofficial dumping grounds. For the enterprising Physics teacher, dumped cars can be the source of many useful parts for the laboratory. Access to a modest backyard workshop is desirable for some of necessary modifications to components before full use can be made of them. In this article I will show how I have used various car parts in the HSC course and also for other applications.

Elective 4AE - Automobile Electrical Systems
Obviously car parts can be used in this elective. Also enough parts can be retrieved from wrecked cars to make it possible for all students to have hands on experience with nearly all aspects of this course. Parts which can be removed from wrecked cars include all the lights, ignition coil, distributor, high tension leads, spark plugs, relays, horn, turn indicator unit, fuses, switches, current regulator, voltage regulator, starter motor and generator (or alternator if it is a late model car).



An ignition system. With 12V D.C. connected as shown, a spark will appear at the spark plug once per revolution of the handle. The condenser can easily be disconnected to observe the effect this produces. The sparks inside the distributor cap are readily observed in this model, but never seen in a vehicle.

The lights should be taken out of their sockets, washed and prepared for use by soldering short bare copper wires to the terminals. Students can then connect them to a power pack using alligator clip connecting leads for a variety of circuits. An important point here is that the car battery is not used for any of the circuits described in this article. Batteries are heavy, dirty and messy. They also can wreck clothes with acid holes. It is much more convenient to use the normal school power pack on 12V DC.
The distributor requires a little modification before use. It needs a small piece of bent rod welded onto the end of the shaft to make a handle. Turning this will then cause the rotor button and cam to turn. Students can then use this distributor and other salvaged components to build a working ignition system. They will need a piece of thick chipboard, some nails to anchor the components, some connecting wire, soldering equipment and a power pack. There is some risk of an electric shock if the wrong parts are touched when the system is operational, but there is no danger for a person enjoying normal health. It is desirable to cut away part of the distributor cap to expose the moving parts inside. Incidentally, this setup will provide enough high tension to operate cathode ray tubes, like the Maltese Cross apparatus, but the result is not as good as from an induction coil.

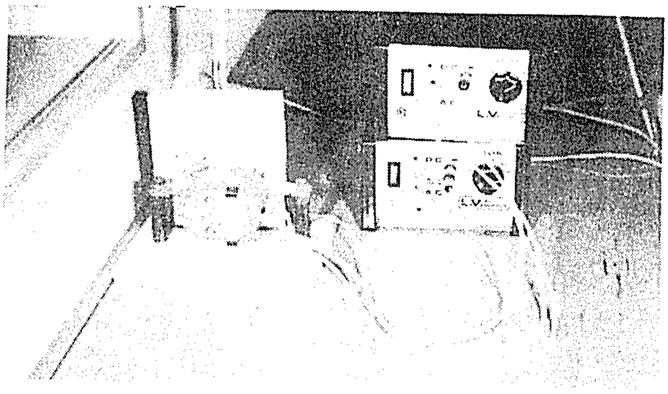
Using other components from cars, students can also construct:

* a relay circuit operating the headlights or horn
* a full headlight, parking light, tail light and number plate light circuit
* a blinker circuit
* a courtesy light circuit
* a starter motor circuit
* a current and voltage regulation system.

Even though a battery is not used to supply power, it is desirable to have a cut-away battery on display. I used a plastic cased battery, spent about half an hour cleaning it on the outside and flushing the acid and residues from the inside, then using a hacksaw to cut away pieces of the case, exposing the plates and connectors. It is also useful to have a cut away ignition coil for display. Care is needed when doing this, as the secondary wires are so thin it is easy to miss them.

Elective 3 - Rotation

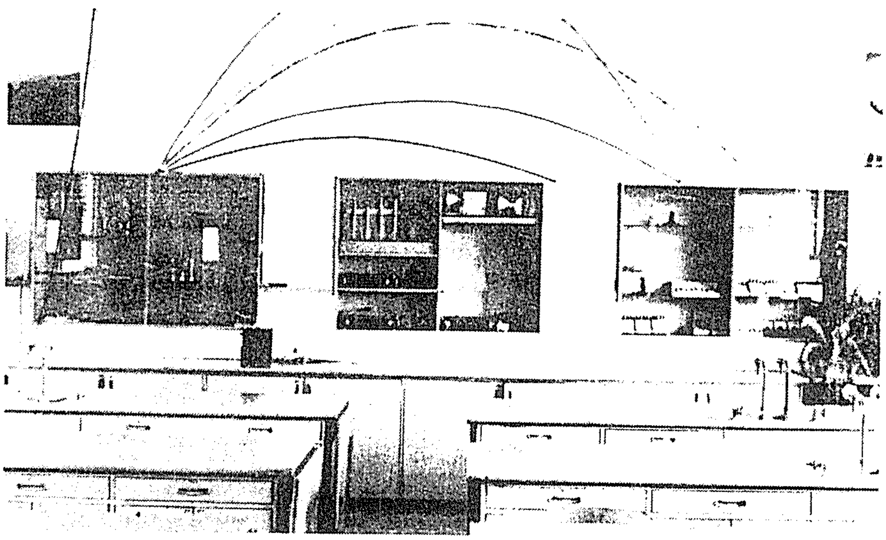
The windscreen wiper motor is a very useful item from a car. Normally it works from 12V DC, but if connected to lower voltages, the motor turns more slowly and will suffer no ill effects. Thus the motor can be used as a variable speed device.



A rotary switch made out of an old windscreen wiper motor. Rainbow cable is used to connect the terminals of the rotary switch to the display.

First, some of the peripheral pieces to the motor have to be removed, leaving a rotating shaft. An arm of any desired length is then welded at right angles to the shaft. Some basic Rotation experiments can be done with this apparatus. A flat circular table can also be connected, either directly or via a pulley and belt, for other experiments.

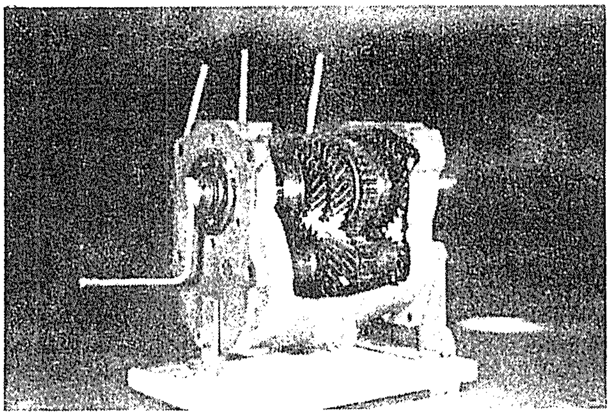
Rotational momentum experiments make use of a Prandtl stool, which can also be made from junked car parts. The base is a steering wheel, upside down. Part of the shaft is left with the wheel and a suitable large ball bearing race is welded to the shaft at a convenient height. Some strengthening braces may need to be added. A circular wooden or metal disc attached to the outside of the race completes the stool. If you have access to an early model Ford Zephyr or car using a similar front suspension system, pull apart this unit and the shaft and bearing are ready to use.



The Projectile Motion Display on the back wall of the Physics Laboratory. The lights come on in a sequence to simulate the flight on a projectile with an initial velocity at an angle of elevation of 45°.

Core Units

The variable speed motor described above can also be incorporated into a rotary switch. A small arm is welded at right angles to the shaft and a 'brush' is attached to the end of the arm. This brush can be any springy conductor metal. This brush makes contact with the top of the nailheads which have been nailed into particle board of thickness less than the length of the nails. The sharp ends of the nails are connected to lights in a display, in which lights go on and off in some sequence. I have used this set up for a simulated projectile motion display across the back wall of the Physics lab and for a simulated SHM display across the top of the blackboard. I have used instrument panel lights from wrecked cars and if it is necessary, of course, used lights of the same wattage for an even effect. If two power packs are used, both the speed of the display and the brightness of the lights can be varied, as the brightness of lights depends on the applied voltage.



A gear box ready for use. Students stand behind the unit, turn the handle with the right hand, and operate the gear levers with the left hand. The effect of the gear changes can be seen by observing the output shaft.

Other Ideas

I have also used retrieved manual gearboxes. The modifications are rather extensive. Shafts need to be cut off close to the casing, bell housing and extension housing removed and mainshaft and input shaft cut off close to the remaining housing. Parts of the casing need to be cut away, so that the action of the cogs can be seen. Also, small handles should be welded onto the remnants of the shafts and onto the gear change shafts, so that gears can be changed while the handle on the input shaft is turned. Some strategically painted sections and mounting onto a solid base completes the job. Students in lower classes love to 'play' with these modified gearboxes and are hopefully learning about gear ratios and mechanical advantage.

The gearbox of a car is surprisingly small, but quite heavy. Motorcycle gearboxes operate differently to those on cars, and it is worth getting hold of one for similar modifications.

I have also modified a differential in the same way, removing all external parts except the differential carrier, and cutting the half shafts just clear of the differential bearings. Handles are welded on to the pinion as well as the half shafts. It is fun to use, but I do not know where it would fit into a Science course.

It may also seem logical to retrieve a whole engine, but I have found it adequate to use lawnmower engines to demonstrate the principles of two and four stroke systems. After dismantling, carefully planned cuts are made with a hacksaw to expose the moving parts. Again, a bit of paint, a solid handle to turn the crankshaft and a solid base are necessary. It is possible to have the spark plug working on these models. To have these engines 'operating' in a display situation requires the connection of a small, low speed motor. I have used a windscreen wiper motor coupled to the crankshaft. The inbuilt reduction gears produce a low enough speed and adequate torque.

The carburettor on a lawnmower is much simpler than the same item on a car and also much easier to use in a demonstration. They are easy to cut away as the metal is an aluminium alloy.

It is also a simple matter to make a working speedometer with a handle turning a small remnant of the speedo cable. A direct connection is not satisfactory, as the speed required is too high for hand turning. Some way of obtaining a turn ratio of about 1:5 is necessary. Cutting away part of the speedo housings shows how it works.

Ball bearings from various ball bearing races can, of course, be used in many experiments. I have found that the larger ball bearings are the most useful.

These are just some of the ways in which car parts can be used. Once you get a few parts you will, no doubt, find many other applications. At our school, we find the most useful parts of all are small light globes. We use them in Junior Science classes for practical work in electrical circuits and conductivity testing, as well as in senior classes, as described above.

Getting Started

The idea of going to a dirty old wrecked car and pulling off bits and pieces may be rather daunting for some teachers. To be honest, the first part of the process is dirty, but one can tackle the job philosophically. That is the price we pay for getting parts that are well made, will last for years, serve our purposes admirably and cost nothing. When the parts are first removed, as much gunk as possible is removed by scraping with a putty knife or similar tool. Then an old dish with a few cm of petrol in it is used. The salvaged article is put in the dish and an old paint brush used to help brush off the rest of the grime. The final clean is done in a rather strong and hot detergent solution. I use Rinso powder. Some parts will need to be re-oiled if they contain moving parts. If cleaned in this way, students will not need to wash hands after handling the parts.

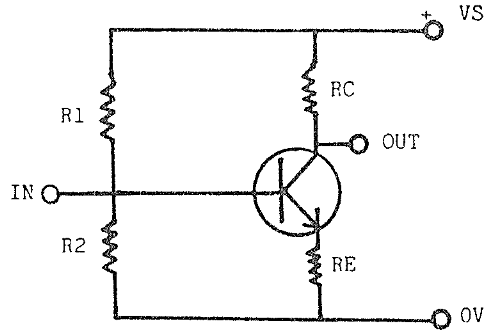
Of course, if you have a friend who is happy to take the parts off the cars, or who has steam cleaning equipment, so much the better, because these two jobs are the dirtiest in the whole process.

Essential tools would be found in a good backyard workshop. A good set of SAE spanners, including sockets, will take apart most British, Australian and US built vehicles and metric sizes are required for European cars. Access to an arc welder is necessary and a good angle grinder saves a lot of hard work, especially when cutting through hardened steel. A heavy all-metal vice on a bench is a must.

THE VOLTAGE DIVIDER COMMON EMITTER TRANSISTOR AMPLIFIER (SEN 1985, Vol. 34 No. 3)
Chris Wiecek, Warilla HS

The use and operation of common emitter circuits is part of the HSC Physics elective, Electronics and the 4 Unit Science elective, Electronics. The most stable and practical of these circuits is with voltage divider bias. (See Figure 1.)

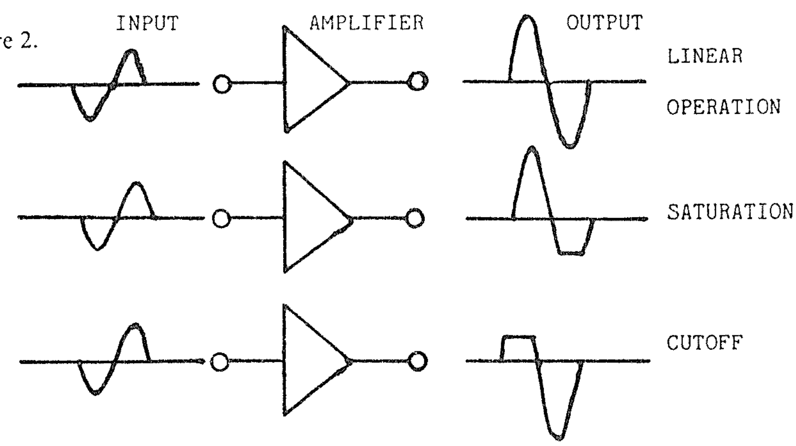
figure 1.



A transistor must be DC biased in order to operate as an amplifier. A DC operating point must be set so that signal variations at the input are reproduced at the output. Biasing is determined by the resistors R1, R2, RC and RE. These define a certain current and voltage condition for the amplifier called the DC operating point or the Q point (quiescent point). Improper biasing will cause distortion in the output signal. This distortion could be saturation or cutoff or both.

Saturation is when an increase in base current does not lead to a corresponding increase in collector current, because the collector current is limited by RC and RE, ie. IC cannot exceed VS/RC + RE. Cutoff occurs when the base voltage is too low to forward bias the base emitter pn junction and therefore no current can flow. (See Figure 2.)

figure 2.



The design of an amplifier circuit is not simple, however values for the resistors R1, R2, RC and RE can be found easily with the use of the following computer program. The program is written for the Apple computer available in many schools. The program requires the input of values of R1, R2, RC and RE with the supply voltage VS and the gain of the transistor Bdc(hFE). The program then computes VB, IC, VE, VCE, etc. and indicates if the transistor is saturated or cutoff. The effect of varying these values can thus be rapidly checked by computer and hence students can design their own amplifying circuit.

Bdc values are available in a variety of sources such as the data section of Dick Smith's catalogues, eg. Bdc for BC548 transistor is quoted at 110-800 in the catalogue and the lower value should be taken. However, a narrower range of Bdc can usually found in manufacturers' data sheets,

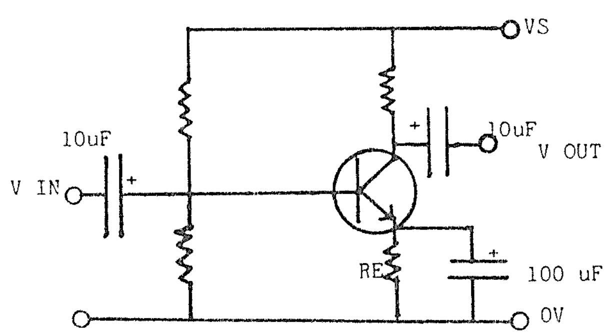
eg. Bdc for a BC548A with IC = 2mA is 110-220 (average value = 180)
Bdc for a BC548B with IC = 2mA is 200-450 (Av = 290)
Bdc for BC548C with IC = 2mA is 420-800 (Av = 500)

Students should be aware that the operating point should allow equal voltage swings above and below the Q point without distortion, ie. VCE + VE = V output should be about half the supply voltage.

The final constraint is on IC. It must be less than the maximum rating allowed for a given transistor, eg. for a BC548 it is 100mA.

Finally have your students construct and test the amplifier with a signal generator and a CRO. Add capacitors at the input and output (Figure 3) and use the CRO to measure the input and output voltages. Compare V output/V input to RC/RE. Finally connect a capacitor in parallel with RE and note the effect on the voltage gain.

figure 3.



Special thanks to Peter Carnaby, Year 9 student, Wally Erven and Jim Webb, staff, for help with the program.

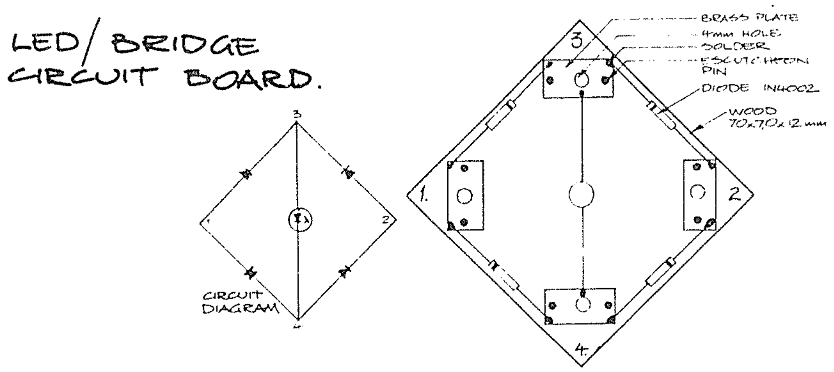
List

```
10   Home
20   Print "This program computes VB, VE, VCE, IB, IC, IE"
30   Print "For the circuit given RI, R2"
40   Print "RC, RE, VS and DC BETA"
50   Print : Print : Print
60   Print "Press a key to continue": Get Z$
70   Home
80   Input "R1 in Ohms"; R1
90   Input "R2 in Ohms"; R2
100  Input "RC in Ohms"; RC
110  Input "RE in Ohms"; RE
120  Input "VS in Volts"; VS
130  Input "DC Beta"; B
140  Home
150  RIN = B*RE
160  If RIN = 10*R2 Then R = R2
165  If R = R2 Then Go to 170
167  R = R2*RIN / (R2 + RIN)
170  VB = (R / (R + R1))*VS
180  VE =VB - .7
190  IE = VE / RE
200  IC = IE
210  VCE = VS - IC*(RC+ RE)
212  RB = (RI*R2) / (RI + R2)
214  IB = (VB - .7) / (RB +(B + I)*RE)
220  If VE 0 Then print "Transistor is cutoff"
230  If VE 0 Then Go to 350
240  If VCE 0 Then print "Transistor is saturated"
260  Print "VB ="; VB; "V"
265  Print "IB ="; IB; "A"
270  Print "VE ="; V; "V"
280  Print "VCE ="; VCE; "V"
290  Print "IC ="; IC; "A"
300  Print "IE =";IE; "A"
350  Input "Do you want to finish. . ."; R$:If R$ = "Y" Then 2000
352  Print "Do you want to restart": Get A$: If A$ = "Y" Then 10
355  Print "Press a key for another": Get Z$
410  Gosub 1000
420  Goto 140
1000 REM variable changes
1010 Print "R1 in Ohms"; R1;: Input Q1$: If Q1$  " "Then R1 = Val(QI$)
```

```
1020 Print "R2 in Ohms"; R2;: Input Q2$: If Q2$  " "Then R2 = Val(Q2$)
1030 Print "RC in Ohms"; RC;: Input Q3$: If Q3$  " "Then RC = Val(Q3$)
1040 Print "RE in Ohms"; RE;: Input Q4$;: If Q4$  " "Then RE = Val(Q4$)
1050 Print "VS in Volts"; VS;: Input Q5$: If Q5$ " "Then VS = Val(Q5$)
1060 Print "DC Beta"; B; Input Q6$: If Q6$     " "Then B = Val(Q6$)
1070 Return
2000 End
```

EXPERIMENTS WITH MULTITAP COILS (SEN 1986, Vol. 35 No. 3)
N.E. Austen, Leichhardt HS

The following experiments use Austen coils, which are hand wound coils with a minimum or two tappings for a number of windings, ranging from 100 to 4000 turns, most having 200 and 2500 turns.



Experiment 1.1

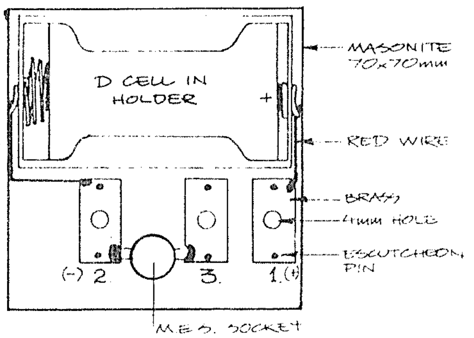
a. Place the coil flat on the bench with labels up. Join the 0 and 2 000 turn terminals to the LED/Bridge Circuit Board terminals 1 and 2 respectively. Balance a bar magnet, standing on its North pole, vertically in the coil-former centre. Snatch the magnet from the coil as rapidly as possible. Describe what happens.
b. Reverse the magnet so that the South pole is snatched from the coil. Describe what happens.
c. Invert the coil, label side now being down. Snatch first North and then South poles from the coil. Describe what happens.
d. Turn the coil over again. Reverse the wires at the coil terminals. Continue as in c. above. Record the results.
e. Hold the coil, still connected to the LED/Bridge circuit, in the left hand in such a fashion that the North pole of the bar magnet can be moved in and out of the coil former centre as rapidly as humanly possible. Record observations.
f. Repeat as in e, substituting the South pole for the North. Record observations.

Experiment 1.2

Join the 0 and 2 000 turn terminals to the 3 and 4 LED/Bridge terminals respectively. Repeat the experiments 1.1 a to f, recording all observations.

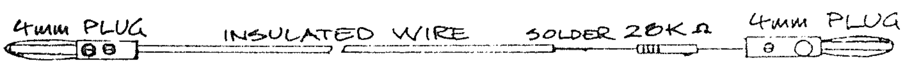
Experiment 2.1

Design a suitable test circuit for the galvanometer. In NSW public schools this is a centre zero, 60 - 0 - 60. The right terminal is normally red, the left black. My circuit tester is shown below. It is used as a conductivity tester and circuit continuity tester with the cell in place and as a voltaic cell with the cell removed, the 2.2v globe being changed to 1.2v and zinc and copper electrodes fitted with 4mm plugs being inserted from below into holes 2 and 3 respectively.



CIRCUIT TESTER BOARD

A lead with 4mm plugs is specially prepared by soldering a KΩ1.4 watt resistor onto the wire at one end before one of the plugs is fitted.



Special Protective Resistor Lead.

Experiment 2.1

a. Connect hole 1 of the Circuit Tester Board to the right hand terminal of the galvanometer using the Protective lead. Connect hole 2 to the left galvanometer terminal. Record results.

b. Reverse the wires at the galvanometer terminals. Record results.

c. Complete the following statements:

   i. when the right galvanometer terminal (red,+) is positive and the left terminal (black, -) is negative, the needle leaves centre zero, moving to the ....

   ii. when the left galvanometer terminal is positive ....

iii. when conventional current flows into the right galvanometer terminal, the needle moves to the ....
iv. when conventional flows into the left galvanometer ....
v. if the galvanometer needle deflects to the left, the right ......
vi. if the galvanometer needle swings right, conventional current is flowing into the .... galvanometer terminal and out of the coil terminal.

Experiment 2.2

Place the coil flat on the bench so that the labels face up. Connect 0 terminal to the left galvanometer terminal and the 250 turn terminal to the right galvanometer terminal. Record observations for experiments 2.2 to 2.4.

a. Slowly introduce the North pole of a bar magnet into the coil former centre.
b. Balance the North pole stationary in the coil.
c. Slowly remove the North pole.
d, e. f. are as a, b, c, in 2.2 above, but the South pole is used.
g. h. Increase the speed of movement of the North pole as in a. and c. above.
i. j. Repeat as in g, h, above, but using the South pole.

Experiment 2.3

Change the lead from the 250 to the 500 turn coil terminal. Move the North pole at a moderate speed into and then out of the coil former centre for each change of coil terminal. Attempt to maintain the same moderate speed for all motion.

Experiment 2.4

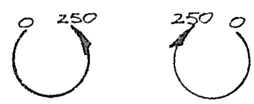
Hold 2 then 3 magnets firmly together, using heavy rubber bands, with LIKE poles in contact. Repeat Experiment 2.2.

Experiment 2.5

a. Summarise the parameters which affect the development of electric current induced in the coil.
b. Tabulate your results for 2.2 a, c, d, f, g, h, i, j, using the following table.

	Coil Terminal Polarity		Induced Current direction	Magnetic Polarity ABOVE Coil by induced Current	Magnetic Pole used and Motion Direction
	Zero	Other	Within Coil		
2a					
c					
d					
etc.					

Coil Terminal Polarity: record as + or - from galvanometer deflection and coil connection to galvanometer terminal. Induced Current Direction: record as within coil.



Note: Induced current direction WITHIN coil is TOWARDS the POSITIVE COIL TERMINAL which makes THAT TERMINAL LIVE and the CONVENTIONAL CURRENT EXTERNAL to the coil is then flowing from + to - coil terminal!

Magnetic Polarity above coil: use Right Hand Rule of Thumb.
Magnetic Pole used: use N towards - for North pole into coil centre.
Motion Direction: use N away; S towards; S away.
From the above table, formulate a rule to predict the direction of the current induced by the motion of the magnetic pole used.

Experiment 3.1

Connect the zero coil terminal to cathode ray oscilloscope earth and the 250 coil terminal to the CRO input. Lay the coil label side up on the bench. Predict the polarity of the coil terminals and the direction of the current within the coil and in the CRO when:

a. a north pole approaches
b. recedes from the coil centre
c. a south pole approaches
d. recedes from the coil centre

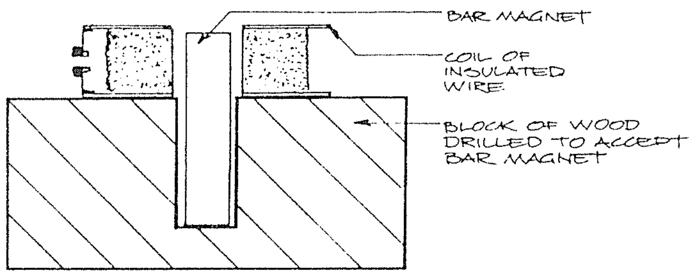
Observe what happens as

e. the speed of motion of the pole is increased
f. the number of turns in the coil is increased
g. the number of like poles is increased
h. the magnetic pole is moved in and out of the coil centre as evenly and rapidly as possible

Experiment 3.2

a. Balance the magnet vertically on the bench and move the coil up and down about the magnet.
b. Attempt to spin the coil about a line perpendicular to the magnets.
c. Examine the standard, hand operated demonstration model dynamo. Compare and contrast the working of this model with the working of the previous coil magnet experiments. Explain the reason for the improved performance of the model.
d. Connect the dynamo terminals to a suitably adjusted CRO.

Experiment 4.1



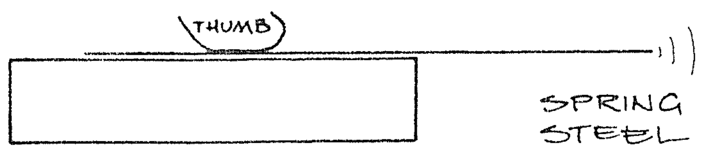
Connect the 0 and 2 000 turn terminals, preferably using a shielded cable, to an amplifier speaker system. (A tape recorder on Pause/Play/Record with an external microphone input would do.)

a. Tap the coil or support moderately firmly with the fingertip or fingernail. What does the resulting sound remind you of?
b. Examine a dynamic microphone insert. Describe and name the working parts. Discuss the operation. How does the insert differ from that used in part a above?
c. Connect the microphone directly to the CRO. Adjust the volts/cm to maximum sensitivity and time/cm to a suitable moderately slow speed. Whistle into the microphone. Comment on the CRO trace.

Experiment 5.1

Use the same support as in 4.1. Connect the 0 and 2 000 turn terminals to a galvanometer. Sweep a soft iron rod or fertile rod horizontally across the upper surface of the coil former fairly slowly from side to side, crossing the centrally located magnet. Record the meter response as the soft iron:

a. approaches
b. recedes from the centrally located magnet
c. increase the sweep speed of the soft iron as desired
d. explain the metre response
   (Hint: try mapping the magnet's field, using iron filings on cardboard sheet, as the soft iron moves towards, then away from the central magnet.)
e. Connect the coil to the amplifier system as in 1.4. Hold, as near to the coil core magnet as possible, vibrating magnetic materials such as:
   i. an electric guitar string stretched between bridges on a suitable piece of fairly dense timber. (A tensioning device could be added)
   ii. tuning forks of all available frequencies
   iii. a piece of spring steel pressed firmly by the left thumb against a short length of suitably dense timber. (Movement of the thumb can alter the length of protruding spring steel. pluck the free end with the right forefinger.)



   iv. spanners, suspended by light nylon fishing line. (Strike with a suitable light hammer such as a nail head.)
   v. a pinch bar, suitably suspended. (Try for harmonics.)
   vi. a high quality steel crow bar, suitably suspended. (Try for harmonics.)
   vii. any other suitable material such as tubes, plates, etc.
f. Be inventive! Experiment wildly! Write the First Movement of the Inductive Symphony!
g. Examine an electric guitar pick-up. Sketch and name the working parts.
h. Compare and contrast the working of the microphone and the pick-up.

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